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**AIRCRAFT
ACCIDENT
REPORT
Pan Am Flight 103
Part I
Consideration of Reasonable Probable Causes**



**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

Part I: Consideration of Reasonable Probable Causes

Abstract and excerpts from AAIB 2/90: The aircraft, Flight PA103 from London Heathrow to New York, had been in level cruising flight at flight level 310 (31,000 feet) for approximately seven minutes when the last secondary radar return was received just before 19.03 hrs. The radar then showed multiple primary returns fanning out downwind. Major portions of the wreckage of the aircraft fell on the town of Lockerbie with other large parts landing in the countryside to the east of the town. Lighter debris from the aircraft was strewn along two trails, the longest of which extended some 130 kilometres to the east coast of England.

The AAIB report concludes that the detonation of an improvised explosive device led directly to the destruction of the aircraft with the loss of all 259 persons on board and 11 of the residents of the town of Lockerbie. Five recommendations are made of which four concern flight recorders, including the funding of a study to devise methods of recording violent positive and negative pressure pulses associated with explosions.

This Smith Pan Am Flight 103 AAR concludes that there are four reasonable alternatives to the bomb explanation based on the subsequent similar accidents of United Airlines Flight 811 and Trans World Airlines Flight 800. Of the four reasonable alternatives, two can be ruled out with confidence: Missile strike and center fuel tank explosion; and two ruled in: Firing of a rather large shotgun and the shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation which closely matches the probable cause of the United Airlines Flight 811 accident. Since the discovered hazards of faulty wiring or switch and nonplug cargo doors currently exist in the five hundred early model Boeing 747s in service, further official investigation is warranted and urgently needed.

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3. Observations:

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4. Observation:

The overall evidence of damage from an explosion of a powerful plastic bomb in the port side of the forward cargo hold is very limited.

5. Observation:

The sudden loud sound on the cockpit voice recorder can be linked to the explosive decompression sound of a cargo door opening in flight on an airliner.

6. Observation:

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7. Observations:

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8. Observations:

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The latch status of the forward cargo door is omitted whilst the latch status of the identical aft cargo door (frames 1800-1920) and the CRAF door is given and stated as 'latched.'

10. Observation:

There is much more airframe damage on the starboard side of the airframe away from the 'bomb' explosion in areas such as the leading edge of the right wing and the right horizontal stabilizer.

11. Observation:

There was a single primary return received by both Great Dun Fell and Claxby radars approximately 16 seconds before SSR returns were lost.

12. Observation:

The aircraft, Flight PA103 from London Heathrow to New York, had been in level cruising flight at flight level 310 (31,000 feet)

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Acronyms and Abbreviations:

CASB, Canadian Aviation Safety Board, now TSB, Transportation Safety Board, of Canada

UK AAIB, United Kingdom Air Accidents Investigation Branch, Farnborough, U.K

NTSB USA, National Transportation Safety Board, United States of America

CVR, cockpit voice recorder

DFDR, digital flight data recorder

ATC, air traffic control

AAR, aircraft accident report

MEC, main equipment compartment

PSI, pounds per square inch

FOD, foreign object damage

IED, improvised explosive device

KTS, knots

TAS, true air speed
IAS, indicated air speed
AI, Air India
PA, Pan Am World Airways
UAL, United Airlines,
TWA, Trans World Airlines
JAL, Japan Air Lines
NAVAVNSAFECEN, Naval Aviation Safety Center
a.c. alternating current
AC advisory circular
AD airworthiness directive
ALPA Air Line Pilots Association
amp ampere
AOA angle-of-attack
APU auxiliary power unit
ARTCC air route traffic control center
ASR airport surveillance radar
ATC air traffic control
ATP airline transport pilot
CAM cockpit area microphone
CFR Code of Federal Regulations
c.g. center of gravity
CVR cockpit voice recorder
CWT center wing fuel tank
d.c. direct current
DNA deoxyribonucleic acid
E/E electrical/electronics
EME electromagnetic environment
EMI electromagnetic interference
EPR engine pressure ratio
F Fahrenheit
FAA Federal Aviation Administration
FARs Federal Aviation Regulations
FBI Federal Bureau of Investigation
FDR flight data recorder
FQIS fuel quantity indication system
GPS global positioning system
HF high frequency
Hg mercury
HIRF high-intensity radiated fields
Hz hertz (cycles per second)
JFK John F. Kennedy International Airport (New York, New York)
MHz megahertz
msl mean sea level
NASA National Aeronautics and Space Administration
NOAA National Oceanic and Atmospheric Administration
NPRM notice of proposed rulemaking
PETN pentaerythritol tetranitrate
P/N part number
psi (pressure expressed in) pounds per square inch
P&W Pratt & Whitney

RDX cyclotrimethylenetrinitramine
SB service bulletin
SDR service difficulty report
SL service letter
S/N serial number
STA body station
STC supplemental type certificate
TWA Trans World Airlines, Inc.
USAF U.S. Air Force
USCG U.S. Coast Guard

References and Source Materials:

AAIB Aircraft Accident Report No 2/90, Pan Am 103, 22 December 1988, Boeing 747
Blacks Law Dictionary, Sixth Edition 1990
Canadian Aviation Bureau Aviation Occurrence, Air India Boeing, 747-237B VT-EFO Report
Indian Kirpal Report, Report Of The Court Investigating Accident To Air India Boeing 747
Aircraft VT-ETO, "Kanishka" On 23rd June 1985
NAVAVNSAFECEN Investigation 69-67, RA-5C, 14 June, 1967
Netherlands Aviation Safety Board AAR 92-11, El Al Flight 1862, Boeing 747
NTSB AAR 90/01 UAL Flight 811, 23 February 1989, Boeing 747
NTSB AAR 92/02 UAL Flight 811, 23 February 1989, Boeing 747
NTSB AAR 00/03 TWA Flight 800, 17 July 1996, Boeing 747
NTSB AAR 93/06, JAL Flight 46E, 31 March, 1993, Boeing 747

Definitions: Definitions as used in this report:

Bomb: 'Bomb' may mean an explosive device designed to release destructive material at high velocity upon detonation; an explosive device placed in an aircraft with an intent to detonate.

Cargo Door: In the Boeing 747 both the forward and aft lower cargo doors are similar in appearance and operation. They are located on the lower starboard side of the fuselage and are outward opening and nonplug. The door opening is approximately 110 inches wide by 99 inches high, as measured along the fuselage.

Cargo Compartments: The forward and aft freight holds are used for the storage of cargo and baggage in standard air-transportable containers. The forward freight compartment has a length of approximately 40 feet and a depth of approximately 6 feet. The containers are loaded into the forward hold through a large cargo door on the starboard side of the aircraft.

Conclusion of fact: An inference drawn from the subordinate or evidentiary facts.

Conclusive evidence: That which is incontrovertible, either because the law does not permit it to be contradicted, or because it is so strong and convincing as to overbear all proof to the contrary and establish the proposition in question beyond reasonable doubt.

Ear Barotrauma: Injury to the tympanic membrane (eardrum) when a sudden pressure differential exists between the middle ear cavity and the external ear.

Evidence: A species of proof, or probative matter, legally presented at the trial of an issue, by the act of the parties and through the medium of witnesses, records, documents, exhibits, concrete objects, etc., for the purpose of inducing belief in the minds of the court or jury as to their contention.

Circumstantial Evidence: The proof of various facts or circumstances which usually attend the main fact in dispute, and therefore tend to prove its existence, or to sustain, by their consistency, the hypothesis claimed. Testimony not based on actual personal knowledge or observation of the facts in controversy, but of other facts from which deductions are drawn, showing indirectly the facts

sought to be proved. Evidence of facts or circumstances from which the existence or nonexistence of fact in issue may be inferred. Inferences drawn from facts proved.

Direct Evidence: Evidence in the form of testimony from a witness who actually saw, heard, or touched the subject of questioning.

Tangible Evidence: Evidence which consists of something that can be seen or touched. In contrast to testimonial evidence, tangible evidence is real evidence.

Expert: One who is knowledgeable in a specialized field, that knowledge being obtained from either education or personal experience. One who by reason of education or special experience has knowledge respecting a subject matter about which persons having no particular training are incapable of forming an accurate opinion or making a correct deduction.

Expert Testimony: Opinion evidence of some person who possesses special skill or knowledge in some science, profession, or business which is not common to the average man and which is possessed by the expert by reason of his special study or experience.

Expert Witness: One who by reason of education or specialized experience possesses superior knowledge respecting a subject about which persons have no particular training are incapable of forming an accurate opinion, or deducing correct conclusions. One possessing, with reference to particular subject, knowledge not acquired by ordinary persons.

Explosion: To burst or cause to burst violently and noisily. The sudden and rapid escape of gases from a confined space, accompanied by high temperatures, violent shock, and loud noise.

Explosive Decompression: Explosive decompression is an aviation term used to mean a sudden and rapid loss of cabin pressurization of higher internal air pressure venting outside to the lower pressure air.

Finding: The result of the deliberations of a jury or a court. A decision upon a question of fact reached as the result of a judicial examination or investigation by a court, jury, referee, coroner, etc. A recital of the facts found.

Outward Opening Nonplug: A type of cargo door which undergoes stress to open in flight under a high pressure differential because it opens outward and the door does not 'plug up' or 'block' the opening.

Premise: A statement of fact or a supposition made or implied as a basis of argument.

Reasonable doubt: The standard used to determine the guilt of innocence of a person criminally charged. Reasonable doubt which will justify acquittal is doubt based on reason and arising from evidence or lack of evidence, and it is doubt which a reasonable man or woman might entertain, and it is not fanciful doubt, is not imagined doubt, and is not doubt that juror might conjure up to avoid performing an unpleasant task or duty. Reasonable doubt is such a doubt as would cause prudent men to hesitate before acting in matters of importance to themselves. Doubt based on reasons which arise from evidence or lack of evidence.

Starboard Side: The right side of the fuselage looking from aft to forward. The port side is the left side looking aft to forward. The starboard side of the aircraft faces the viewer when the nose is to the right. Both cargo doors are on the starboard side of the Boeing 747.

Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation: Mechanical explanation for the inflight breakup of Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 as caused by an explosion in the forward cargo compartment of explosive decompression when the forward cargo door ruptures open in flight, probably at one or both of the midspan latches and probably caused by faulty wiring inadvertently turning on the door unlatch motor.

Introduction:

This AAR has been created by an independent aircraft accident investigator who has no affiliation with the manufacturer, law enforcement agencies, attorney, airlines, or victim's families. Much of

the text is quoted verbatim from official government documents. The primary document is Aircraft Accident Report No 2/90 (EW/C1094) produced by the Air Accidents Investigation Branch of the United Kingdom.

Any reference to an 'explosion' does not imply a bomb explosion. An 'explosion' can be caused by a fuel tank explosion or an explosive decompression explosion. A reference to an 'improvised explosive device' does not imply a bomb as there are devices which can be improvised, intentionally or unintentionally, to cause an explosion such as blasting caps, firecrackers, fireworks, starting pistols, and gas tanks. Evidence of explosive residue does not imply the explosion of a bomb as the residue could have been put there intentionally as part of a dog sniffing drill or the residue could have come from troop's clothing rubbing on the seats and thus have a benign explanation. Whenever there is evidence of an explosion in an aircraft, and there certainly was an explosion in Pan Am Flight 103, corroborating evidence is required to rule in or rule out the possibilities of a bomb explosion, a missile hit, a fuel tank explosion, or an explosive decompression explosion from metal fatigue or inadvertent fuselage rupture such as caused by a suddenly ruptured open cargo door. Each premise shall be examined and supported by evidence.

This Smith AAR has the benefit of hindsight with the ability to review and analyze dozens of subsequent Boeing 747 accidents as well as evaluating previous accidents of other types. There exists an early model Boeing 747 at Bruntingthorpe that suffered a staged bomb explosion in a cargo compartment which left much actual evidence. There also exists an early model Boeing 747, United Airlines Flight 811, that suffered an explosion of explosive decompression in a cargo compartment which left much evidence. Pan Am Flight 103 was an early model Boeing 747 that suffered an explosion in a cargo compartment which left much evidence which can be compared with other similar events. This AAR shall compare the evidence of Pan Am Flight 103 to that of the other other three explosive events to identify which of the three is most closely matched, the bomb explosion, the center fuel tank explosion, or the ruptured open cargo door explosive decompression explosion.

1. Factual Information

1.1 History of the Flight

Boeing 747, N739PA, arrived at London Heathrow Airport from San Francisco and parked on stand Kilo 14, to the south-east of Terminal 3. Many of the passengers for this aircraft had arrived at Heathrow from Frankfurt, West Germany on a Boeing 727, which was positioned on stand Kilo 16, next to N739PA. These passengers were transferred with their baggage to N739PA which was to operate the scheduled Flight PA103 to New York Kennedy. Passengers from other flights also joined Flight PA103 at Heathrow. After a 6 hour turnround, Flight PA103 was pushed back from the stand at 18.04 hrs and was cleared to taxi on the inner taxiway to runway 27R. The only relevant Notam warned of work in progress on the outer taxiway. The departure was unremarkable.

Flight PA103 took-off at 18.25 hrs. As it was approaching the Burnham VOR it took up a radar heading of 350° and flew below the Bovingdon holding point at 6000 feet. It was then cleared to climb initially to flight level (FL) 120 and subsequently to FL 310. The aircraft levelled off at FL 310 north west of Pole Hill VOR at 18.56 hrs. Approximately 7 minutes later, Shanwick Oceanic Control transmitted the aircraft's oceanic clearance but this transmission was not acknowledged. The secondary radar return from Flight PA103 disappeared from the radar screen during this transmission. Multiple primary radar returns were then seen fanning out downwind for a considerable distance. Debris from the aircraft was strewn along two trails, one of which extended

some 130 km to the east coast of England. The upper winds were between 250° and 260° and decreased in strength from 115 kt at FL 320 to 60 kt at FL 100 and 15 to 20 kt at the surface.

Two major portions of the wreckage of the aircraft fell on the town of Lockerbie; other large parts, including the flight deck and forward fuselage section, landed in the countryside to the east of the town. Residents of Lockerbie reported that, shortly after 19.00 hrs, there was a rumbling noise like thunder which rapidly increased to deafening proportions like the roar of a jet engine under power. The noise appeared to come from a meteor-like object which was trailing flame and came down in the north-eastern part of the town. A larger, dark, delta shaped object, resembling an aircraft wing, landed at about the same time in the Sherwood area of the town. The delta shaped object was not on fire while in the air, however, a very large fireball ensued which was of short duration and carried large amounts of debris into the air, the lighter particles being deposited several miles downwind. Other less well defined objects were seen to land in the area.

The AAIB report concludes that the detonation of an improvised explosive device led directly to the destruction of the aircraft.

2. Premise Explanations for Pan Am Flight 103

The AAIB report conclusion is interpreted by most to mean a bomb blew Pan Am Flight 103 out of the sky. That interpretation may not be correct as there are alternatives based on subsequent similar accidents such as United Airlines Flight 811 and Trans World Airlines Flight 800. An alternative probable cause to Pan Am Flight 103 must be considered if the alternative were:

1. Plausible.
2. Reasonable.
3. Well documented by official investigative reports.
4. Has close precedent.
5. Reveals current hazard.

There is one solid conclusion and five reasonable explanations for probable cause based upon subsequent similar fatal inflight accidents to early model Boeing 747s:

- 2.1. Explosion in flight in the forward cargo compartment leading to inflight breakup as an initial event and is a solid conclusion.
- 2.2. Missile strike. (Brought up by Trans World Airlines Flight 800.)
- 2.3. Center fuel tank explosion with undetermined ignition source. (Brought up by Trans World Airlines Flight 800.)
- 2.4. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup. (Brought up by United Airlines Flight 811.)
- 2.5. Explosion in flight from a bomb in the forward cargo compartment. (Brought up by Air India Flight 182, Pan Am Flight 103, Trans World Airlines Flight 800, and United Airlines Flight 811.)
- 2.6. Firing of a rather large shotgun in forward cargo compartment. (Brought up by Pan Am Flight 103.)

2.1 Premise: Explosion in flight in the forward cargo compartment leading to inflight breakup.

2.1.2 Discussion: The unanimous conclusion by authorities of a sudden inflight breakup implies an explosion of explosive decompression since the hull of Pan Am Flight 103 was pressurized to a 8.9 pounds per square inch differential between inside and outside air at 31000 feet above mean sea level. Explosive decompression is a symptom of a sudden hull breakup, not the cause. If the hull is not compromised by a break, hole, or tear in it, decompression does not occur. Any break of substantial size in that highly pressurized hull, for reasons such as a bomb explosion, a midair collision, or an inadvertently opened cargo door, would be sufficient to cause an explosive decompression and subsequent partial or full inflight breakup. Inflight breakups can be caused by an explosive decompression which can be caused by a 'bomb' explosion, or structural failure, or an inadvertent door opening. All bomb explosions, all structural failures, and all inadvertent door openings do not cause inflight breakups; in fact, many aircraft have suffered those events and landed safely. On the other hand, any one of those events has the potential to cause an inflight breakup and have done so in the past, depending on the sizes of the bomb, the skin tear, or the open door.

When a catastrophic event occurs, such as an explosion of a bomb or a large door opening in flight, much evidence is left behind for investigators to recover, examine, and evaluate specific to that cause. All explosions of any kind leave certain similar evidence regardless of the cause of the explosion. Evidence of an explosion does not imply a 'bomb' nor an explosive decompression from any source. Even when there is a single piece of tangible evidence that indicates a specific type of explosion such as a bomb, structural failure, or an inadvertent door opening, other corroborative evidence is required to sustain the conclusion of the type of explosion since all types of explosions can cause similar evidence and explosive decompressions from any source can mimic a bomb explosion and vice versa.

From AAIB Aircraft Accident Report No 2/90: '2.14 Summary: The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage.' UK AAIB Report 2/90 Page 56. 'The forward fuselage and flight deck area separated from the remaining structure within a period of 2 to 3 seconds.' UK AAIB Report 2/90 Page 57 'Although the pattern of distribution of bodies on the ground was not clear cut there was some correlation with seat allocation which suggested that the forward part of the aircraft had broken away from the rear early in the disintegration process.' UK AAIB Report 2/90 Page 30

The evidence which shows there was an explosion in the forward cargo compartment can be summed up by the following evidence.

- A. Inflight breakup just forward of the wing causing damage to wing leading edge and engines.
- B. Debris pattern showing nose came off the aircraft in flight.
- C. Suddenness of event.
- D. Sudden loud sound on the CVR.
- E. Abrupt power cut to the FDR.
- F. First pieces to leave aircraft were from area just forward of the wing.
- G. Trajectory pattern shows explosion in forward cargo compartment.
- H. Outwardly peeled skin in forward cargo compartment area.

There is now revealed a new structural weakness in the forward cargo compartment for Boeing 747s and by implication all pressurized jets with large outward opening nonplug cargo doors.

For the Boeing 747: The four eight foot vertical slices in the fuselage skin for the sides of the forward and aft cargo doors are held in place by only one latch in each side. So, each eight foot vertical slice has one midspan latch to hold four feet closed on each side of it. The midspan latch has no locking sector on the latching cam to prevent inadvertent back driving in flight. All of the eight bottom latches on each door, for a total of sixteen latches, have locking sectors. The four midspan latches for the two cargo doors have none. The weakness is at the midspan latches and the absence of locking sectors. One latch with no locking sector for eight feet of fuselage slice is not enough. The midspan latch ruptures open in flight and causes the tell tale peeled back and down skin from the latch such as in Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 and apparently Air India Flight 182.

2.1.3 Conclusion: There was an explosion in the forward cargo compartment which caused an explosive decompression that led the the inflight breakup of Pan Am Flight 103.

There are many ways for an explosion to occur in the forward cargo compartment at the forward cargo door: (Current official opinion in parentheses)

- A. Bomb explosion. (Partially accepted for two flights, ruled out for two flights.)
- B. Crew or passenger error. (Ruled out for all flights.)
- C. Electrical fault in switch or wiring. (Accepted for two flights, ruled out for two flights.)
- D. Pneumatic overpressure. (Ruled out for all flights.)
- E. Cargo shift. (Ruled out for all flights.)
- F. Compressed air tank explosion. (Ruled out for all flights.)
- G. Fire in compartment. (Ruled out for all flights.)
- H. Missile strike. (Ruled out for all flights.)
- I. Midair collision. (Ruled out for all flights.)
- J. Fuel tank explosion. (Accepted for one flight, ruled out for three flights.)
- K. Stowaway. (Ruled out for all flights.)
- L. Electromagnetic interference. (Ruled out for all flights.)
- M. Comet or meteor. (Ruled out for all flights.)
- N. Space debris. (Ruled out for all flights.)
- O. Turbulence. (Ruled out for all flights.)
- P. Out of rig door. (Ruled out for all flights.)
- Q. Lightning. (Ruled out for all flights.)
- R. Metal fatigue. (Ruled out for all flights.)
- S. Improperly latched. (Initially accepted for one flight, then ruled out for all flights.)
- T. Design error. (Accepted for one flight, ruled out for three flights.)
- U. Repair error. (Ruled out for all flights.)
- V. Maintenance error. (Accepted for one flight, ruled out for three flights.)
- W. Collision with terrain. (Ruled out for all flights.)

Of the twenty three ways to cause an explosive decompression in the forward cargo compartment in flight, only five are reasonable for Pan Am Flight 103 based on precedent and other evidence.

1. Missile strike. (Brought up by Trans World Airlines Flight 800.)
2. Center fuel tank explosion with undetermined ignition source. (Brought up by Trans World Airlines Flight 800.)
3. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup. (Brought up by United Airlines Flight 811.)
4. Bomb. (Brought up by Air India Flight 182 and Pan Am Flight 103 and Trans World Airlines Flight 800 and United Airlines Flight 811.)
5. Rather large shotgun. (Brought up by Pan Am Flight 103.)

2.2.1 Premise: Surface-to-air or air-to-air missile strike inflight:

2.2.2. Discussion: A missile could have struck the aircraft in flight. Only a hit in the forward cargo compartment would have caused the abrupt power cut to the recorders and the sudden loud sound in addition to all the other evidence of inflight damage to the airframe forward of the wing. There is no corroborative evidence that a missile struck Pan Am Flight 103. There were no military planes nearby nor reports of missing missiles, there were no reports of missile sightings at event time, there is no wreckage evidence of residue, missile casing, pitting, or cratering which follows a high explosive detonation, and there was no missile explosion sound on the CVR. The reasons that a missile strike was ruled out for Trans World Airlines Flight 800 are the same reasons that a missile strike can be ruled out for Pan Am Flight 103.

Page 257 to page 259 of NTSB AAR 00/03 for Trans World Airlines Flight 800: ‘2.2.1.2 Consideration of a High-Energy Explosive Device Detonation (Bomb or Missile Warhead) Several factors led to speculation that the accident might have been caused by a bomb or missile strike. These factors included heightened safety and security concerns because of the 1996 Olympics then being held in the United States, the fact that TWA flight 800 was an international flight, and the sudden and catastrophic nature of the in-flight breakup. In addition, numerous witnesses to the accident reported seeing a streak of light and then a fireball, which some people believed represented a missile destroying the airplane. Further, some anomalous primary radar targets were recorded by the Islip, New York, radar site in the general vicinity of TWA flight 800 at the time of the accident that apparently could not be explained. Accordingly, the Safety Board considered the possibility that a bomb exploded inside the airplane or that a missile warhead from a shoulder-launched missile exploded upon impact with the airplane. Testing performed by the Federal Bureau of Investigation (FBI) found trace amounts of explosives on three separate pieces of airplane wreckage (described by the FBI as a piece of canvaslike material and two pieces of floor panel). However, none of the damage characteristics typically associated with a high-energy explosion of a bomb or missile warhead (such as severe pitting, cratering, petalling, or hot gas washing) were found on any portion of the recovered airplane structure, including the pieces on which the trace amounts of explosives were found. Only about 5 percent of the airplane's fuselage was not recovered, and none of the areas of missing fuselage were large enough to have encompassed all of the damage that would have been caused by the detonation of a bomb or missile. Although several large holes are visible in the reconstructed portion of the airplane fuselage, almost all of the structure that originally filled in these holes is attached to the remaining structure but is folded either inward or outward. No area of structure in the reconstructed portion of the airplane contained any unexplained holes large enough to represent the entry point of a missile. Further, the victims remains showed no evidence of injuries that could have been caused by high-energy explosives, nor was there any damage to the airplane seats and other interior components consistent with a high-energy explosion. Investigators considered several scenarios to determine how the trace amounts of explosive residue might have gotten on the wreckage from the accident airplane. Trace amounts of explosive residue could have been transferred to the contaminated pieces from the military personnel (and their associated clothing, boots, and equipment) that were on board the accident airplane when it was used to transport troops during the Gulf War in 1991. In addition, explosives were placed and then removed from several locations in the accident airplane during a dog-training explosive detection exercise about 1 month before the accident. Despite being unable to determine the exact source of the trace amounts of explosive residue found on the wreckage, the lack of any corroborating evidence associated with a high-energy explosion indicates that these trace amounts did not result from the detonation of a high-energy explosive device on TWA flight 800. Accordingly, the Safety Board concludes that the in-flight breakup of TWA flight 800 was not initiated by a bomb or a missile strike.”

2.2.3 Conclusion: Based upon lack of corroborative evidence, a missile strike as a probable cause for Pan Am Flight 103 may be ruled out.

2.3.1 Premise: Center Fuel Tank explosion with undetermined ignition source:

2.3.2 Discussion: There was a fire in the wing and engine number three but no evidence of inflight fire around the center fuel tank. The center tank may have been on fire as it fell, but it did not explode according to the recovered wreckage. The sound on the CVR was not a fuel tank explosion sound. The pieces of wreckage which left the plane first were not from the center fuel tank. The sides of the fuselage near the center tank were damaged in much different degrees and should be evenly bilateral if a center tank exploded. None of the passenger victims were burned extensively. The reasons for determining that Trans World Airlines Flight 800 suffered an inflight center fuel tank explosion with undetermined ignition source are absent for Pan Am Flight 103.

2.3.3 Conclusion: Based upon lack of corroborative evidence, a center fuel tank explosion with undetermined ignition source as a probable cause for Pan Am Flight 103 may be ruled out.

2.4.1 Premise: Explosion in the forward cargo compartment on the starboard side caused by explosive decompression caused by structural failure of a ruptured open forward cargo door at one or both of the midspan latches caused by faulty electrical wiring or switch shorting on the door unlatch motor.

2.4.2. Discussion:

A. The wiring/cargo door explanation is plausible as a sequence of events from wiring short to airframe breakup as it all could happen according to physical laws of nature.

B. It's reasonable because of the explosive effects of an unintentional hull rupture in a pressurized jet as learned from the Comet and DC-10 experiences.

C. It's well documented by the Kirpal Report, the Canadian Aviation Safety Board AAR, Three NTSB AARs (90/01 and 92/02, and 00/03), AAIB Aircraft Accident Report No 2/90 (EW/C1094), and aviation safety public docket information.

D. It has close precedent because of United Airlines Flight 811 (NTSB AAR 92/02).

E. It reveals a current hazard of aging defective wiring in early Boeing 747s of which about 500 are still in service and it reveals a poorly designed outward opening nonplug cargo door.

The corroborative evidence is literally in volumes: NTSB AAR 90/01 and NTSB AAR 92/02 for United Airlines Flight 811 and AAIB 2/90 for Pan Am Flight 103. Below are specific matches between PA 103 and UAL 811 gleaned from those government AARs.

Both were:

Aged.

High flight time.

Early model-100.

Poly x wired.

Boeing 747.

Experienced hull rupture forward of the wing on right side in cargo door area.

Shape of hull rupture forward of the wing on the right side is rectangle with specific rectangular shape.

Fodded number three engine.

On fire number three engine.

Sudden sound on CVR

Loud sound on the CVR.

Short duration sound on the CVR.

Abrupt power cut to FDR.
 Outwardly peeled and down skin in cargo door area from aft midspan latch.
 Longitudinal break at midline of the forward cargo door at midspan latch.
 More severe inflight damage on starboard side.
 At least nine never recovered bodies.
 Vertical fuselage tear lines forward of the wing and aft of cargo door.
 Torn off and missing skin in forward cargo door area on starboard side.
 Outward peeled skin on upper forward fuselage.
 Destruction initially thought to be have been caused by a bomb.

The photographs and analysis which matches up the forward cargo door areas of Pan Am Flight 103, United Airlines Flight 811, Trans World Airlines Flight 800, and a drawing of Air India Flight 182 are shown in Part III: Door Story, of this Smith AAR.

A detailed examination of a possibly defective forward cargo door was done in the later AAR for United Airlines Flight 811 (NTSB 92/02). It includes close examination of the latch pins for bluing from overpressure, the hinges for overtravel, the torque tubes for bending, the bellcranks for slack, the overpressure relief doors for operation, the manual locking handle for status, the locking sectors for damage, and other evaluations. There is no discussion of the forward cargo door in AAIB 2/90 and in fact, the latching status is omitted as well as a picture of the starboard side door area. The forward cargo door area does need the depth of examination that was conducted for United Airlines Flight 811 and described in Part II: Comparison, of this Smith AAR.

A bomb is one interpretation one may make when words of ‘improvised explosive device’ are stated but it could also be a complex device called a forward cargo door with latches, cams, bellcranks, overpressure relief doors, manual locking handle, viewing ports, and torque tubes. It could be an explosive device because of the experience of United Airlines Flight 811 where the crew described the initial event when the forward cargo door opened inflight as a “tremendous explosion.” The door may have been improvised by fate that let polyimide aromatic insulated wiring called Poly X be installed in planes that are now flying at twice the expected in service life using wiring that is prone to chafing and cracking, especially in the presence of moisture. (The forward cargo compartment has a special bilge built in to hold the excess moisture in the compartment from condensation.) The outward opening device may be considered improvised by the designers who created nonplug cargo doors while making the passenger doors the safer plug type.

The cargo doors on Boeing 747s have been the subject of many Airworthiness Directives over the years to correct problems such as bent sills, exposed wiring, too soft metal, and poorly placed safety placards There are many Service Difficulty Reports of leaking seals requiring emergency landings. Cargo doors on Boeing 747s are extremely complex devices, proven capable of explosive action, poorly designed, and prone to failure. They have failed in flight before in addition to the fatal event of United Airlines Flight 811. (From NTSB 92/02: Previous Cargo Door Incident On March 10, 1987, a Pan American Airways B-747-122, N740PA, operating as flight 125 from London to New York, experienced an incident involving the forward cargo door. According to Pan Am and Boeing officials who investigated this incident, the flightcrew experienced pressurization problems as the airplane was climbing through about 20,000 feet. The crew began a descent and the pressurization problem ceased about 15,000 feet. The crew began to climb again, but about 20,000 feet, the cabin altitude began to rise rapidly again. The flight returned to London. When the airplane was examined on the ground, the forward cargo door was found open about 1 1/2 inches along the bottom with the latch cams unlatched and the master latch lock handle closed. The cockpit cargo door warning light was off.) (Note that Pan Am Flight 125

was the same airline as Pan Am Flight 103 and the aircraft, N740PA, is the sister ship of N739PA- PA 103.)

Cargo doors can be, under certain conditions of flight, improvised explosive devices. They are not bombs although they may cause similar damage if they inadvertently rupture open in flight.

2.4.3 Conclusion: Based upon an abundance of corroborative evidence, (Detailed in Part II: Comparison) an electrical problem of wiring or switch causing a hull rupture in flight as a probable cause for Pan Am Flight 103 may be ruled in pending further investigation.

2.5.1. Premise: Explosion of a improvised explosive device in the forward cargo compartment on the left side.

2.5.2 Discussion: The evidence which explains how the investigators may have been misled into the belief that a relatively mild blast was actually a powerful bomb explosion is detailed in Part IV: Comparison of reports, of this Smith AAR. The evidence which refutes an explosion of a bomb in the forward cargo compartment on the left side can be summed up by the following evidence.

If a powerful bomb were to explode in the forward cargo hold of Pan Am Flight 103 on the left side, certain corroborating evidence would be present such as hot-gas pitting on pieces of metal, punctures, shrapnel, explosive residue, pitting, cratering, explosive type injuries to passengers sitting in the cabin, timer, fuze, and a bomb explosion sound on the cockpit voice recorder.

For Pan Am Flight 103:

- A. Pitting: Present
- B. Cratering: Present
- C. Hot gas washing: Absent
- D. Holes: Absent
- E. Punctures: Absent
- F. Shrapnel: Absent
- G. Explosive residue: Found.
- H. Burn injuries to passengers sitting in the cabin: Absent
- I. Sooted metal: Present
- J. Timer or bomb casing: Fragments of plastic.
- K. Fuze: Absent
- L. Bomb explosion sound on the cockpit voice recorder: Absent

Bombs have been considered for Air India Flight 182 and Trans World Airlines Flight 800 as well as Pan Am Flight 103 and thus extensively investigated. The same reasons for ruling out a bomb for Trans World Airlines Flight 800 are the same reasons to rule it out for Air India Flight 182 and Pan Am Flight 103.

The NTSB states in AAR 00/03 regarding Trans World Airlines Flight 800: Page 180, footnote 368: 'Evidence of a bomb explosion included deformation of materials away from a location at the height of the passenger seat pan, hot-gas pitting damage on multiple pieces of wreckage that formed a pattern radiating from the same location (including into the CWT), punctures radiating from the same location, and shrapnel. Further, according to the FBI's laboratory report, No. 91204034 S YQ YB/91207052 S YQ YB, dated January 30, 1990, chemical analysis of a piece of wreckage from the right side of the CWT identified the presence of RDX and PETN high explosive. These two explosives comprise about 86 percent of the composition of SEMTEX, which is a rubberlike material manufactured by Synthesia Corporation of Semtin, Czechoslovakia,

primarily for use in mining and other civil engineering activities. According to the FBI, SEMTEX has been used by criminal and terrorist elements in Europe since 1966. (SEMTEX was identified as the material used in the bomb placed on Pan Am flight 103. For additional information, see section 1.11.1.2.)’

Page 257 to page 259 of NTSB AAR 00/03 for Trans World Airlines Flight 800 ‘2.2.1.2 Consideration of a High-Energy Explosive Device Detonation (Bomb or Missile Warhead) Several factors led to speculation that the accident might have been caused by a bomb or missile strike. These factors included heightened safety and security concerns because of the 1996 Olympics then being held in the United States, the fact that TWA flight 800 was an international flight, and the sudden and catastrophic nature of the in-flight breakup. In addition, numerous witnesses to the accident reported seeing a streak of light and then a fireball, which some people believed represented a missile destroying the airplane. Further, some anomalous primary radar targets were recorded by the Islip, New York, radar site in the general vicinity of TWA flight 800 at the time of the accident that apparently could not be explained. Accordingly, the Safety Board considered the possibility that a bomb exploded inside the airplane or that a missile warhead from a shoulder-launched missile exploded upon impact with the airplane. Testing performed by the Federal Bureau of Investigation (FBI) found trace amounts of explosives on three separate pieces of airplane wreckage (described by the FBI as a piece of canvaslike material and two pieces of floor panel). However, none of the damage characteristics typically associated with a high-energy explosion of a bomb or missile warhead (such as severe pitting, cratering, petalling, or hot gas washing) were found on any portion of the recovered airplane structure, including the pieces on which the trace amounts of explosives were found. Only about 5 percent of the airplane's fuselage was not recovered, and none of the areas of missing fuselage were large enough to have encompassed all of the damage that would have been caused by the detonation of a bomb or missile. Although several large holes are visible in the reconstructed portion of the airplane fuselage, almost all of the structure that originally filled in these holes is attached to the remaining structure but is folded either inward or outward. No area of structure in the reconstructed portion of the airplane contained any unexplained holes large enough to represent the entry point of a missile. Further, the victims remains showed no evidence of injuries that could have been caused by high-energy explosives, nor was there any damage to the airplane seats and other interior components consistent with a high-energy explosion. Investigators considered several scenarios to determine how the trace amounts of explosive residue might have gotten on the wreckage from the accident airplane. Trace amounts of explosive residue could have been transferred to the contaminated pieces from the military personnel (and their associated clothing, boots, and equipment) that were on board the accident airplane when it was used to transport troops during the Gulf War in 1991. In addition, explosives were placed and then removed from several locations in the accident airplane during a dog-training explosive detection exercise about 1 month before the accident. Despite being unable to determine the exact source of the trace amounts of explosive residue found on the wreckage, the lack of any corroborating evidence associated with a high-energy explosion indicates that these trace amounts did not result from the detonation of a high-energy explosive device on TWA flight 800. Accordingly, the Safety Board concludes that the in-flight breakup of TWA flight 800 was not initiated by a bomb or a missile strike.”

From AAIB Aircraft Accident Report No 2/90 ‘1.13 Medical and pathological information The results of the post mortem examination of the victims indicated that the majority had experienced severe multiple injuries at different stages, consistent with the in-flight disintegration of the aircraft and ground impact. There was no pathological indication of an in-flight fire and no evidence that any of the victims had been injured by shrapnel from the explosion. There was also no evidence which unequivocally indicated that passengers or cabin crew had been killed or injured by the effects of a blast. Of the casualties from the aircraft, the majority were found in areas which

indicated that they had been thrown from the fuselage during the disintegration. Although the pattern of distribution of bodies on the ground was not clear cut there was some correlation with seat allocation which suggested that the forward part of the aircraft had broken away from the rear early in the disintegration process. The bodies of 10 passengers were not recovered and of these, 8 had been allocated seats in rows 23 to 28 positioned over the wing at the front of the economy section.'

Most of the required evidence that corroborates a bomb explosion on Pan Am Flight 103 is missing and those few traces of residue can now be explained as benign based upon Trans World Airlines Flight 800. Evidence of Semtex was found on both Pan Am Flight 103 and Trans World Airlines Flight 800 yet called benign for one and could be for the other, too. The two tiny pieces of plastic hard evidence are suspect as to location and purpose.

The initial event time was officially determined to be the sudden loud sound on the CVR. The initial event of the sudden loud sound is likely the explosive decompression sound when the rupture/structural failure occurred and the air molecules rushed out making the sudden loud sound on the CVR. Pan Am Flight 103 has been matched to Air India Flight 182 in the AAIB report. This initial event sudden sound on the CVR for Air India Flight 182 has been matched to a DC-10 explosive decompression sound when its cargo door opened in flight. All four Boeing 747 sudden sound events have been matched by NTSB in Chart 12 of the public docket for Trans World Airlines Flight 800 (Chart 12 on cover sheet of Part II). The accidents are all linked together by the sudden loud sound on the CVR which is the primary, not the secondary event, of the structural failure when the door ruptured open and explosive decompression ensued. (Detailed in Part II: Comparisons.)

The time of the structural failure of the ruptured open forward cargo door on the starboard side and the opening of the 20 inch hole on the port side was determined to be the initial event time of the sudden loud sound by the AAIB wreckage distribution drawings in Appendix B in the AAIB report which are based upon the distance from the datum line of the retrieved wreckage. These data showed at initial event time the large rectangular shaped fuselage skin area around the shattered forward cargo door occurred at the same time as the 20 inch hole on the smoother port side. As the seconds progressed, the subsequent drawings show the damage holes getting bigger and bigger with the starboard cargo door side hole always remaining larger.

Based on wreckage distribution data, it can be deduced by the evidence that the 20 inch hole on the port side occurred at about the same time as the twenty foot by thirty foot hole on the starboard side and both were at initial event time of the sudden loud sound on the CVR.

2.5.3 Conclusion: Based upon a very small amount or a benign finding of corroborative evidence, an explosion of a powerful explosion from a bomb as a probable cause for Pan Am Flight 103 may be ruled doubtful.

2.6.1 Premise: Firing of a rather large shotgun in a baggage container.

2.6.2. Discussion: The firing of a rather large shotgun may have given evidence which led investigators to conclude a powerful bomb had been detonated causing the destruction of Pan Am Flight 103. (Detailed in Part IV: Comparison of Reports.)

The evidence and AAIB interpretation indicated a relatively mild directed blast existed a corner of a baggage container, traveled about 25 inches and caused a 20 inch hole in the fuselage skin. The sound of the mild directed blast was not heard on the cockpit voice recorder. Bombs are loud,

spherical, and powerful. Shotgun blasts are relatively mild and directed.

The damage in the baggage container and adjacent area was from a mild directed blast as if a rather large shotgun had gone off at close range. (AAIB stated in Aircraft Accident Report No 2/90 (EW/C1094) section: 1.12.2.1 Fuselage: "Where these panels formed the boundary of the shatter zone, the metal in the immediate locality was ragged, heavily distorted, and the inner surfaces were pitted and sooted - rather as if a very large shotgun had been fired at the inner surface of the fuselage at close range," and 8. Analysis: "With the two container reconstructions placed together it became apparent that a relatively mild blast had exited container 4041 through the rear lower face to the left of the curtain and impinged at an angle on the forward face of container 7511.)'

An AAIB official opined the cause of the damage he/she personally viewed to be as if a rather large shotgun had been fired at the fuselage at close range. It may not have been exactly a shotgun but some other type of directed firearm.

This AAIB opinion may have been correct in its assessment of the cause of the mild blast, pitting, sooting, distortions, ragged, and shattered skin as if a very large shotgun had been fired at the inner surface of the fuselage at close range. It may be that pitting, sooting, distortions, ragged, and shattered skin could also have been erroneously interpreted as evidence of a bomb explosion.

Loaded guns have been inserted into baggage holds of airliners before and have been accidentally discharged as detailed in Appendix K. (April 26, 2000 Gun goes off in bag being loaded into jet. Associated Press - Portland "A high-powered handgun went off in the baggage compartment of an Alaska Airlines jetliner on the tarmac at Portland International Airport, sending a bullet into the passenger compartment within inches of passengers' feet. Nobody was injured.")

Shotgun cartridges give sooty residue when fired. A shotgun fires in a directed manner and would give a relatively mild blast compared to a high explosive bomb. The sound of the weapon firing is not heard on the cockpit voice recorder because the power had been abruptly cut in the adjacent main equipment compartment after the tremendous explosive decompression when the huge hole appeared on the starboard side of the hold or the gunshot was over shouted by the tremendous noise from the huge hole and the explosive decompression.

The evidence corroborates the firing of a device called a rather large shotgun in a baggage container which caused a relatively mild directed blast which resulted in a 20 inch hole in the fuselage skin on the port side. This damage was not sufficient to cause the nose to come off Pan Am Flight 103 because the structure was designed to withstand a hold that size in the pressurized hull by the presences of stiffeners, ribs, and belts. The firing of the shotgun was after the explosive decompression because the sound of the gunshot is not on the cockpit voice recorder.

The location in the forward cargo compartment in the baggage container which had its lower quadrant blown way may have held a rather large shotgun which was stored in baggage, was loaded, and was safe unless a tremendous explosion happened nearby. A tremendous explosion did happen nearby when the opposite fuselage blew out when a huge twenty foot by forty foot hold appeared suddenly where the forward cargo door and skin above it used to be. The rather large shotgun went off, the relatively mild explosion left soot on a rib, burst through the corner of the baggage container, went 25 inches and made a 20 inch hole in the port side of the fuselage. A sooty rib was soon found on the ground and immediately incorrectly declared proof a bomb had gone off instead of a shotgun cartridge.

2.6.3 Conclusion: Based upon the presence of corroborative evidence, the firing of rather large shotgun in the forward cargo hold Pan Am Flight 103 may be ruled in as occurring but ruled out as the cause of the subsequent structural failure pending further investigation.

2.7. Summary: To summarize conclusions about Pan Am Flight 103 based upon subsequent events such as United Airlines Flight 811 and Trans World Airlines Flight 800:

1. There was an explosion in the forward cargo compartment inflight because of corroborative evidence.
2. Missile strike unlikely because of absence of corroborative evidence. (Brought up by Trans World Airlines Flight 800.)
3. Center fuel tank explosion with undetermined ignition source unlikely because of absence of corroborative evidence. (Brought up by Trans World Airlines Flight 800.)
4. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup likely because of presence of corroborative evidence and the precedent of United Airlines Flight 811. (Brought up by United Airlines Flight 811.)
5. Bomb explosion unlikely because of absence of corroborative evidence.. (Brought up by Air India Flight 182 and Pan Am Flight 103 and Trans World Airlines Flight 800 and United Airlines Flight 811.)
6. Firing of a rather large shotgun in baggage container is likely to have occurred because of presence of corroborative evidence. (Brought up by Pan Am Flight 103.)

3. Sequence of disintegration. Combined from Air Accidents Investigation Branch Aircraft Accident Report No 2/90 (EW/C1094) and Smith AAR:

Water may have met the cracked insulated wire in the cargo door area. The now exposed and bare wire shorted against the metal fuselage. The electricity then flowed around safety cutout switches and powered on the cargo door actuator unlatch electric motor which attempted to rotate all ten cam sectors to unlocked positions around their latching pins. The eight lower cam sectors may have been prevented from unlatching around the latching pins because of the bottom eight locking sectors. However, the two midspan latches had no locking sectors to prevent the inadvertent rotation of the midspan latching cams around the midspan latching pins. The midspan cams may have turned just past center with no locking sectors to prevent the backdriving of the cams, an operation only supposed to be allowed on the ground. Possibly other factors such as an out of rig cargo door, a poor repair job on the door area, the slack in bellcranks, torque tubes, and worn latch pins may combined to have allowed the two midspan latches to rotate just past center permitting the almost 100,000 pounds of internal pressure on the 99 inch by 110 inch door to rupture outward inflight relieving the maximum pressure differential on the internal fuselage.

The eight foot by nine foot squarish forward cargo door would have instantly burst open at the midspan latches sending the latches, door material, and large pieces of fuselage skin spinning away, possibly being picked up on radar. The forward cargo compartment would have spewn its contents outward onto the starboard side of the fuselage. The severe explosion of explosive decompression caused the forward cargo door to be fractured and shattered into a few large pieces and many small pieces which gave a frayed appearance from an outward force. The door skin peeled out and down from the aft midspan latch.

The top part of the door swung outward and upward on its hinge and then separated taking large vertical pieces of fuselage skin with it, exposing stringers and bulkheads. The resulting damage zone appeared as a huge rectangle of shattered door, skin, and stringers. Some pieces of the door and fuselage skin flew directly aft and impacted the leading edge of the right wing, the vertical stabilizer and the right horizontal stabilizer inflight.

This explosion of explosive decompression blew out a large hole about twenty feet wide and thirty feet high on the starboard side of the nose forward of the wing. It looked as if a bomb had gone off inside the forward cargo hold. Fuselage skin was peeled outward at various places on

the starboard side of the nose.

This door, located on the forward starboard side of the aircraft, was broken horizontally about one half of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. The cargo door pieces and the adjacent skin had holes, flaps, fractures, inward concavity, tears, deformities, outward bent petals, curls, missing pieces, cracks, separations, curved fragments, spikes, and folds.

The now uncompressed air molecules rushed out of the huge hole equalizing the high pressure inside the fuselage to the low pressure outside the aircraft while making a sudden very loud audible sound. This sudden rushing outward air was recorded on the Cockpit Voice Recorder as a sudden loud sound. The sound did not accurately match any bomb explosion sounds on other aircraft but did match the explosive decompression sound on another wide body airliner, a DC-10 cargo door open event.

The tremendous explosive force in the forward cargo hold severely disrupted the adjacent main equipment compartment which housed power cables and abruptly shut off power to the Flight Data Recorders. The resulting data tapes showed a sudden loud audible sound followed by an abrupt power cut to the flight data recorder and the cockpit voice recorder.

The initial explosion triggered a sequence of events which effectively destroyed the structural integrity of the forward fuselage. Little more than remained between stations 560 and 760 (approximately) than the window belts and the cabin sidewall structure immediately above and below the windows, although much of the cargo-hold floor structure appears to have remained briefly attached to the aircraft.

The main portion of the aircraft simultaneously entered a manoeuvre involving a marked nose down and left roll attitude change, probably as a result of inputs applied to the flying control cables by movement of structure.

Failure of the left window belt then occurred, probably in the region of station 710, as a result of torsional and bending loads on the fuselage imparted by the manoeuvre (i.e. the movement of the forward fuselage relative to the remainder of the aircraft was an initial twisting motion to the right, accompanied by a nose up pitching deflection).

The forward fuselage deflected to the right, pivoting about the starboard window belt, and then peeled away from the structure at station 800. During this process the lower nose section struck the No 3 engine intake causing the engine to detach from its pylon. This fuselage separation was apparently complete within 3 seconds of the explosion.

Structure and contents of the forward fuselage struck the tail surfaces contributing to the destruction of the outboard starboard tailplane and causing substantial damage to the port unit. This damage occurred approximately 600 metres track distance after the explosion and therefore appears to have happened after the fuselage separation was complete.

Fuselage structure continued to break away from the aircraft and the separated forward fuselage section as they descended.

The aircraft maintained a steepening descent path until it reached the vertical in the region of 19,000 feet approximately over the final impact point. Shortly before it did so the tail fin began to disintegrate.

The mode of failure of the fin is not clear, however, flutter of its structure is suspected.

Once established in the vertical dive, the fin torque box continued to disintegrate, possibly permitting the remainder of the aircraft to yaw sufficiently to cause side load separation of Nos 1, 2 and 4 engines, complete with their pylons.

Break-up of the rear fuselage occurred during the vertical descent, possibly as a result of loads induced by the yaw, leaving a section of cabin floor and baggage hold from approximately stations 1241 to 1920, together with 3 landing gear units, to fall into housing at Rosebank Terrace.

The main wing structure struck the ground with a high yaw angle at Sherwood Crescent.'

4. Hindsight Pattern. A pattern has been revealed which includes Pan Am Flight 103.

Significant Direct and Tangible Evidence Obtained for Four B747 Breakups in Flight

	AI 182	PA103	UAL 811	TWA 800
Boeing 747	Yes	Yes	Yes	Yes
Early model -100 or -200	Yes	Yes	Yes	Yes
Polyimide wiring (Poly X type)	Yes	Yes	Yes	Yes
Sudden airframe breakup in flight (partial or total)	Yes	Yes	Yes	Yes
Breakup occurs amidships	Yes	Yes	Yes	Yes
High flight time (over 55,000 flight hours)	No	Yes	Yes	Yes
Aged airframe (over 18 years of service)	No	Yes	Yes	Yes
Previous maintenance problems with forward cargo door	Yes	Maybe	Yes	Maybe
Initial event within an hour after takeoff	No	Yes	Yes	Yes
Initial event at about 300 knots while proceeding normally in all parameters	Yes	Yes	Yes	Yes
Initial event has unusual radar contacts	Maybe	Yes	Yes	Yes
Initial event involves hull rupture in or near forward cargo door area	Yes	Yes	Yes	Yes
Initial event starts with sudden sound	Yes	Yes	Yes	Yes
Initial event sound is loud	Yes	Yes	Yes	Yes
Initial event sound is audible to humans	Yes	Yes	Yes	Yes
Initial event followed immediately by abrupt power cut to data recorders	Yes	Yes	Yes	Yes
Initial event sound matched to explosion of bomb sound	No	No	No	No
Initial event sound matched to explosive decompression sound in wide body airliner	Yes	Yes	Yes	Yes
Torn off skin on fuselage above forward cargo door area	Yes	Yes	Yes	Yes
Unusual paint smears on and above forward cargo door	Maybe	Maybe	Yes	Yes
Evidence of explosion in forward cargo compartment	Yes	Yes	Yes	Yes
Foreign object damage to engine or cowling of engine number three	Yes	Yes	Yes	Yes
Fire/soot in engine number three	Maybe	Yes	Yes	Yes
Foreign object damage to engine or cowling of engine number four	Yes	Yes	Yes	Yes
Right wing leading edge damaged in flight	Yes	Maybe	Yes	Maybe
Vertical stabilizer damaged in flight	Yes	Yes	Yes	Maybe
Right horizontal stabilizer damaged in flight	Yes	Yes	Yes	Yes
More severe inflight damage on starboard side than port side	Yes	Yes	Yes	Yes
Port side relatively undamaged by inflight debris	Yes	Yes	Yes	Yes
Vertical fuselage tear lines just aft or forward of the forward cargo door	Yes	Yes	Yes	Yes
Fracture/tear/rupture at a midspan latch of forward cargo door	Maybe	Yes	Yes	Yes
Midspan latching status of forward cargo door reported as latched	No	No	No	No
Airworthiness Directive 88-12-04 implemented (stronger lock sectors)	No	No	No	Yes
Outwardly peeled skin on upper forward fuselage	Yes	Yes	Yes	Yes
Rectangular shape of shattered area around forward cargo door	Yes	Yes	Yes	Yes
Forward cargo door fractured in two longitudinally	Yes	Yes	Yes	Maybe
Status of aft cargo door as intact and latched	Yes	Yes	Yes	Maybe
Passengers suffered decompression type injuries	Yes	Yes	Yes	Yes
At least nine missing and never recovered passenger bodies	Yes	Yes	Yes	Yes
Wreckage debris field in two main areas, forward and aft sections of aircraft	Yes	Yes	No	Yes
Initial official opinion of probable cause as bomb explosion.	Yes	Yes	Yes	Yes
Initial official opinion modified from bomb explosion	Yes	Yes	Yes	Yes
Structural failure considered for probable cause	Yes	Yes	Yes	Yes
Inadvertently opened forward cargo door considered for probable cause	Yes	No	Yes	Yes
Official probable cause as bomb explosion	Yes	Yes	No	No
Official probable cause as 'improvised explosive device'	No	Yes	No	No
Official probable cause as explosion by unstated cause	Yes	No	No	No
Official probable cause as explosion in center fuel tank with unknown ignition source	No	No	No	Yes
Official probable cause as improper latching of forward cargo door	No	No	Yes	No

Official probable cause as switch /wiring inadvertently opening forward cargo door	No	No	Yes	No
"Bomb' allegedly loaded two flights previous to detonation flight	Yes	Yes	N/A	N/A
"Bomb' allegedly loaded one flight previous to detonation flight	N/A	N/A	N/A	Yes
Takeoff after sunset on fatal flight	Yes	Yes	Yes	Yes
Takeoff after scheduled takeoff time on fatal flight	Yes	Yes	Yes	Yes
"Bomb' allegedly goes off on ground after a flight	N/A	N/A	N/A	N/A
Significant Direct and Tangible Evidence Obtained for Four B747 Breakups in Flight	AI 182	PA103	UAL 811	TWA 800

The pattern above is based on similar evidence in only four early model Boeing 747 inflight fatal events. The pattern is clear yet complex and detailed. When a forward cargo door ruptures open in flight, certain things have to happen and they happened for Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800.

The significance of the pattern is that it is possible only one cause is for all and that cause, faulty electrical wiring or switch, still exists, is a current hazard. There is urgency.

An additional significance of the pattern is that enough current hard evidence exists to justify a supplemental safety investigation into Air India Flight 182, Pan Am Flight 103, based upon subsequent similar accidents such as United Airlines Flight 811 and Trans World Airlines Flight 800 from which much new relevant knowledge was gained, such as the aging aircraft study which revealed the dangers of Kapton/Poly X wiring and that an electrical problem can cause a cargo door to rupture open in flight causing fatalities in a Boeing 747.

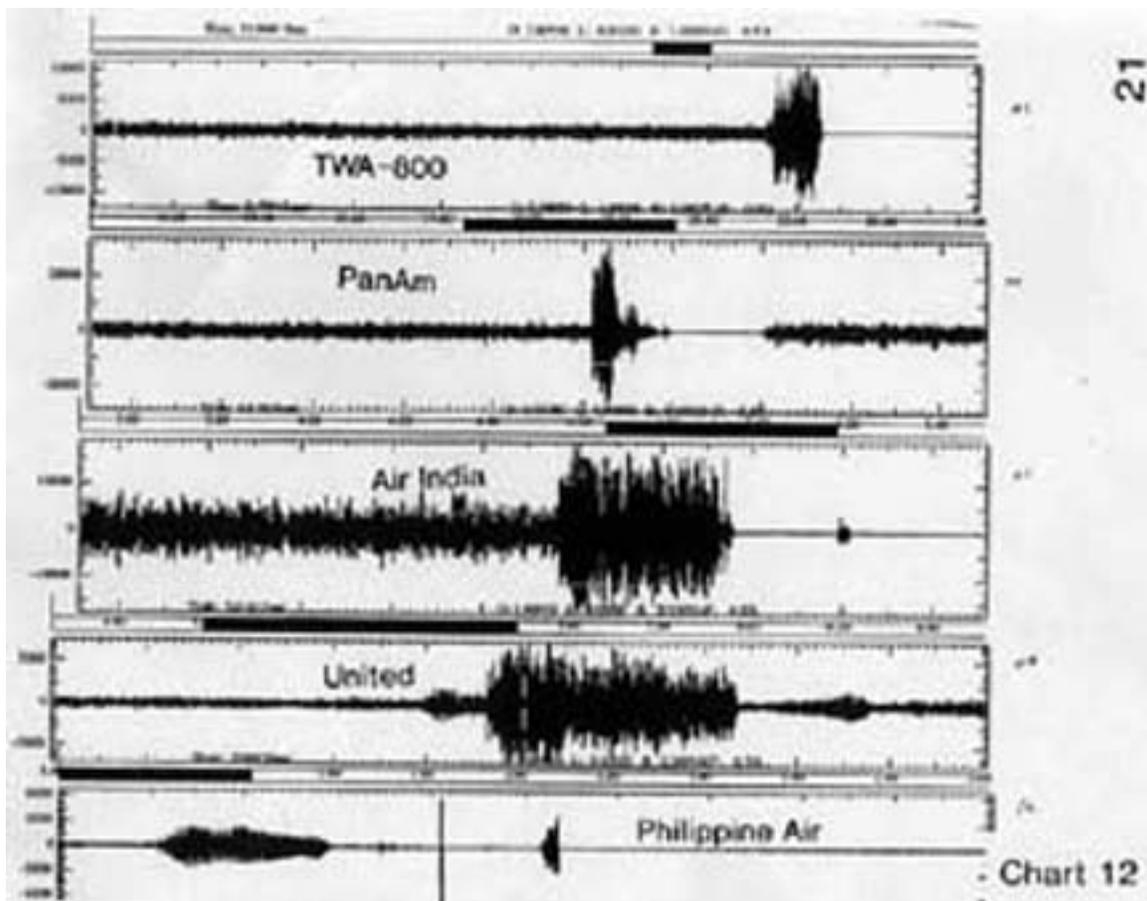
5. Specific Conclusions for Pan Am Flight 103:

- A. Explosion in forward cargo compartment likely.
- B. A powerful Semtex bomb exploding in port side of forward cargo compartment unlikely and not supported by evidence.
- C. Firing of a rather large shotgun with a baggage container at close range to the fuselage likely and supported by evidence.
- D. Explosion decompression caused by missile strike or center fuel tank explosion with unknown ignition source unlikely and not supported by evidence.
- E. A shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup sequence likely and supported by evidence and precedent.

6. Concluding Comment on Part I: The hazard of faulty wiring or switch still exists in the five hundred early model Boeing 747s in service and the design flaw of inadequate midspan latches with no locking sectors exists in many thousands of Boeing airliners in service today. These hazards present dangers which are preventable.

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**AIRCRAFT
ACCIDENT
REPORT
Pan Am Flight 103
Part II
Comparison to Similar Accidents**



**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

Part II: Comparison to Similar Accidents

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6. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had breakups in their airframes in a similar amidships location.
7. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had at least nine never recovered bodies.
8. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had passengers that showed explosive decompression type injuries and no evidence of bomb explosion injuries.
9. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had experienced a sudden, loud, audible sound on the cockpit voice recorder at event start time:
10. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had the source of the sudden, loud, audible sound as a bomb explosion disputed and the source of the sudden, loud, audible sound as an explosive decompression supported.
11. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had an abrupt power cut to the data recorders immediately after a sudden, loud, audible sound at event start time.
12. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had an explosion in or adjacent to the forward cargo compartment.
13. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had similar shattered fuselage skin in and around the forward cargo door.
14. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had relatively mild damage on the port side of the nose forward of the wing directly opposite the shattered zone around the forward cargo door at the same initial event time.
15. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had similar damage to their airframe structures from inflight ejected debris.
16. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had foreign object damage to engine number three.
17. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had incomplete reports of the status of the forward cargo door.
18. Air India Flight 182, Pan Am Flight 103, and Trans World Airlines Flight 800, and United Airlines Flight 811 to a much lesser extent, had similar debris patterns on the surface of the ground or sea bottom.
19. Summary of matching evidence for all aircraft:
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1. Introduction: There is a history of aviation accidents not being fully explained in the first AAR.

Icarus was the first aviation related fatality and his mythic accident was said to have been caused when the wax by which he affixed the wings to his body melted when he flew too close to the sun; the wings came off, and down he went.

The AAR might have been worded thus:

When King Minos of Crete found out that his son, the Minotaur, had been killed and Theseus had escaped with his daughter, he was angry with Daedalus for not building a complex enough labyrinth. In revenge, he imprisoned the inventor in there with his young son Icarus. Determined to escape from this unfair punishment, Daedalus fashioned two pairs of wings, each on a wooden frame, lined with many feathers which were fixed with beeswax.

When the inventor had finished, he and his son climbed up to the highest part of the labyrinth, catching the wind and looking down into the sea which surrounded the walls. They fixed their wings on each other and planned their escape. Daedalus told Icarus that he was to keep his arms wide apart so as to catch even the slightest breath of wind and to keep close behind his father, keeping a straight course between the sun and the sea. "For if you fly too close to the sea, your feathers will dampen and you will drown under the weight of the frame. If you fly too close to the sun however, the beeswax will melt and the feathers will loosen. Remember these words and you will be safe."

The two of them then leapt from the walls, Daedalus going first and Icarus following closely behind. However, Icarus soon became bolder as he flew effortlessly in the skies and left his father's straight course of flight to twirl and loop in the air. As his loops became bolder, he flew higher and forgot his father's warning. All too late, he noticed the feathers falling off the frame for he had flown too close to the sun. He called out to his father as he fell from the sky and into the sea where he drowned.

Daedalus had heard his cries but it was too late for Icarus had already fallen. He recovered the body which had swept up onto a nearby island and buried it there, naming it 'Icaria'. He then flew on and found refuge in Etna's land.

This explanation was not meant to be examined closely, of course, as the explanation makes no sense. For instance, how does one affix large wings to a human body with beeswax; how does one fly high enough to get too close to the sun, how did Icarus find enough energy to get off the ground in the first place, and lastly, who was to blame? Was it the designer Daedalus who used the defective wax? Was it the King who gave them reason to fly away? Was it pilot error of flying his craft outside accepted operating limits? What could be done to prevent such a

reoccurrence? Better flight training, better adhesives? Aviation accident investigations are very complex affairs with many parties interested in the outcome. (Note that laypersons who have heard about Icarus are usually unaware of the wise admonition to not fly too low and are only aware of the warning hazard of flying too high. Only the fatal accident causes are remembered.)

The probable cause for Icarus' accident made sense at the time of telling, but now, years later, we understand it did make a good story and fulfilled the wishful thinking of those listening to it but was clearly impossible based on the tangible, circumstantial, and direct evidence.

With the introduction of the jet age in commercial airliners in the late 1950's, such as the Comet from the United Kingdom, large hulls were pressurized and subjected to many cycles of pressurizing and depressurizing. Cracks appeared in the fuselage which led to structural failure and powerful explosive decompressions which appeared as an explosion which led to the inflight breakup of the early airliner.

There is a history of inadvertent explosive decompressions in commercial airliners being initially suspected as bomb explosions. Those events are usually controversial. (Appendix B, Avianca Accident) It is an understandable error of deduction because an explosion of explosive decompression closely mimics a bomb in producing explosive effects such as ejecting material at high velocity, making a loud noise, being unexpected, and not supposed to happen inside an airliner as well as cratering, pitting curling, folding, and tearing metal. An explosive decompression is referred to in accident investigations as an 'explosion' and described by a crewmember who suffered through one as a 'tremendous explosion.'

All explosions give some similar evidence; it is the corroborating evidence for a specific type of explosion that is required before a determination may be made as to type of explosion, such as bomb, fuel tank, or explosive decompression. Explosive decompression is the most difficult to determine because it leaves no residue or soot and therefore, its determination lies largely in the absence of corroborating evidence for an alternative explanation of residue, timer, fuze, ignition source, burns, or soot. An explosive decompression does need a highly pressurized vessel and a rupture location identified whereas the others do not. Bombs and fuel tanks can explode on the ground; fatal explosive decompressions from any source have all occurred inflight.



The solution to the early mystery of the Comet crashes was achieved by matching two similar events in the similar aircraft which left similar evidence.

Excerpts of corroborative statements to support the Comet explosive decompression explanation: (Appendix C, Comet Accidents)
<http://www.tech.plym.ac.uk/sme/FailureCases/FAILURE.htm>

Professor M Neil James Webpage:
<http://www.plym.tech.ac.uk/sme/uoa30/structur.htm>

Comet Airliner: Jet transportation age began in on May 5 1952 when the De Havilland Comet 1 began scheduled flights from London to Johannesburg. In April 1953, a Tokyo to London service was inaugurated – flying time for the 10 200 mile distance dropped from 85 hours to 36 hours. The Comet had a cruising speed of 490 mph at 35 000 feet and a range of 1 750 miles with a payload of 44 passengers.

The cabin was pressurized to maintain a pressure equivalent to 8 000 feet at an aircraft altitude of 40 000 feet, which was required for efficient operation of the engines. This gave a pressure differential of 8.25 psi (56 kPa) across the fuselage – twice the value previously used. De Havilland conducted ‘many tests’ to ensure structural integrity of the cabin. However, a series of 3 accidents occurred where Comet aircraft disintegrated in flight:

(a) Investigation by R.A.E. (Excerpts) The loss of Yoke Peter and Yoke Yoke presented a problem of unprecedented difficulty, the solution of which was clearly of the greatest importance to the future, not only of the Comet, but also of Civil Air Transport in this country and, indeed, throughout the world. They thought it necessary to satisfy themselves about the structural integrity of the aircraft, in particular of the cabin and the tail and to consider in more detail possible sources of explosion and loss of control. But at the time when their attention became directed to fatigue of the pressure cabin they were influenced chiefly by the apparent similarity of the circumstances of the two accidents, and by the fact that the modifications carried out after Elba seemed to rule out many of the other possible causes.

(2) There were serious lessons resulting from explosive decompression and deceleration.

G-ALYV after leaving Calcutta – May 1953. Violent storms were thought to be involved and some wreckage was recovered. No firm conclusions drawn as to cause.

G-ALYP over Elba – January 1954 after 1 286 cabin pressurisation cycles. Little wreckage was recovered and no major problems found in fleet inspection. Fire was assumed the most likely cause and modifications made to improve fire prevention and control. Aircraft returned to service.

G-ALYY flying as SA 201 after leaving Rome – April 1954. and all Comet 1 aircraft were subsequently withdrawn from service.

A more intensive effort was made to recover the wreckage of G-ALYP using underwater television cameras for the first time. About 70% of the aircraft was recovered and reconstructed at Farnborough. The Royal Navy was charged with getting the relevant fuselage piece of G-ALYP from the sea (using simulation trials, based on the way the aircraft was now thought to break up in flight, to establish the likely position of this part of the aircraft on the seabed. This was recovered within a few hours of searching and showed, in the language of the coroner, the ‘unmistakable fingerprint of fatigue’. The fatigue crack was associated with the

stress concentrations of the rather square rear ADF window cutout (stress of 315 MPa at edge of window), and with a bolt hole around the window (although the stress at the bolt position was only 70 MPa).

In the 1960s a new type of airliner came into production called a 'widebody', the DC-10 (Appendix D, DC-10 Accidents) and the Boeing 747 (Appendix E, Boeing 747 History). These aircraft had a much larger cabin to accommodate several hundred passengers. This larger size of the hull required greater pressurization loads on the internal fuselage which were underestimated by designers. Subsequently two flights of the DC-10 suffered explosive decompressions in flight from inadvertent cargo door openings which left evidence of a sudden loud sound on the cockpit voice recorder which was used to match to later explosive decompression events in another wide body airliner, the Boeing 747 in Air India Flight 182. The design of the outward opening nonplug cargo door was criticized as inadequate for both types of aircraft in subsequent accident reports.



June 12, 1972
 McDonnell Douglas DC-10-10 N103AA, American Airlines
 Over Windsor, Ontario
 Mechanical Failure due to Design Flaw/Human Error
 Occupants: 67
 Fatalities: 0

Following takeoff from Detroit, the rear cargo door blew off due to a door latch system that had been damaged by ground crew members. The loss of pressurization caused the cabin floor to buckle and damaged the hydraulic control lines of the aircraft. The captain, having trained himself in simulator sessions to fly the aircraft using its throttles (a method called "differential thrust steering"), made an emergency landing in Detroit.

March 3, 1974
 McDonnell Douglas DC-10-10 TC-JAV Turk Hava Yollari - THY
 Outside Paris, France
 Mechanical Failure due to Design Flaw/Human Error
 Occupants: 346
 Fatalities: 346

The latch mechanism of the aft cargo door, the design of which was susceptible to damage, had been damaged before the accident. Before takeoff the door had not been secured properly. Shortly after takeoff from Paris, the door failed. The resulting depressurization led to the disruption of the floor structure, causing six

passengers and parts of the aircraft to be ejected, rendering No.2 engine inoperative, and impairing the flight controls so that it was impossible for the crew to regain control of the aircraft.

On February 24, 1989, United Airlines Flight 811, a Boeing 747-122, experienced an explosive decompression as it was climbing between 22,000 and 23,000 feet after taking off from Honolulu, Hawaii, en route to Sydney, Australia with 3 flightcrew, 15 flight attendants, and 337 passengers aboard.

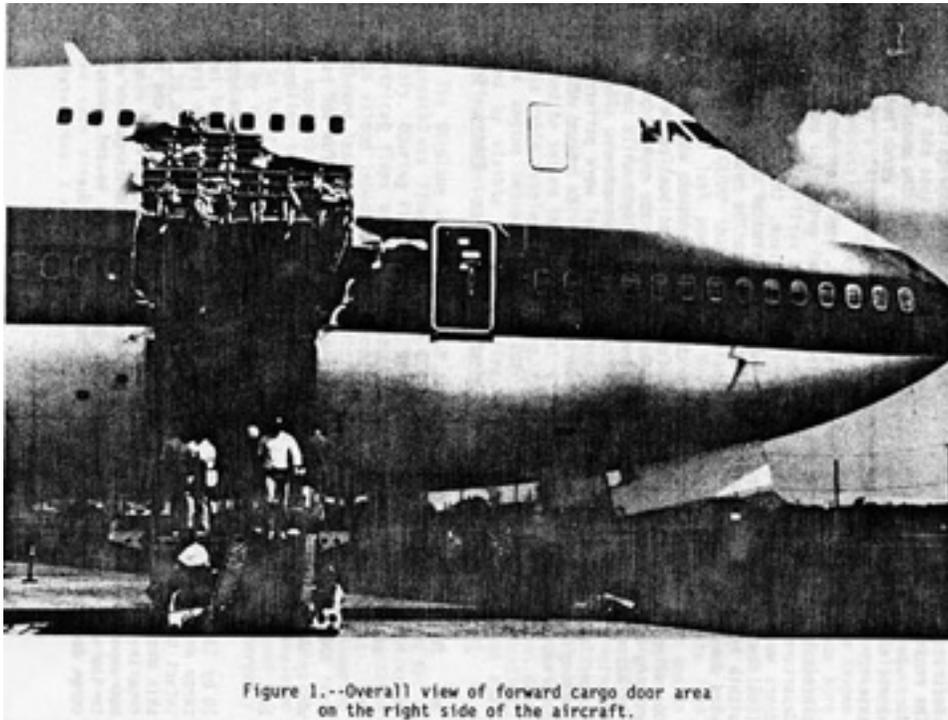


Figure 1.--Overall view of forward cargo door area on the right side of the aircraft.

After an investigation, the NTSB issued AAR 90/01 which concluded:

'The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the improperly latched forward lower lobe cargo door in flight and the subsequent explosive decompression.' NTSB also stated: 'The next opportunity for the FAA and Boeing to have reexamined the original assumptions and conclusions about the B-747 cargo door design and certification was after the findings of the Turkish Airline DC-10 accident in 1974 near Paris, France. The concerns for the DC-10 cargo door latch/lock mechanisms and the human and mechanical failures, singularly and in combination, that led to that accident, should have prompted a review of the B-747 cargo door's continuing airworthiness. In the Turkish Airlines case, a single failure by a ramp service agent, who closed the door, in combination with a poorly designed latch/lock system, led to a catastrophic accident. The revisions to the DC-10 cargo door mechanisms mandated after that accident apparently were not examined and carried over to the design of the B-747 cargo doors. Specifically, the mechanical retrofit of more positive locking mechanisms on the DC-10 cargo door to preclude an erroneous locked indication to the flightcrew, and the incorporation of redundant sensors to show the position of the latches/locks, were not required to be retrofitted at that time

for the B-747.'

After extensive efforts from the family of one of the victims, the forward cargo door pieces of United Airlines Flight 811 were retrieved from the bottom of the ocean and it was discovered that, in fact, the cargo door had been properly latched, thus exonerating the accused ground baggage handler of the deaths of nine innocent passengers. The NTSB issued another aircraft accident report, AAR 92/02, with the corrected probable cause, apparently the only known time that two aircraft accident reports have been written about the same accident.

NTSB AAR 92/02 states: "Thus, as a result of the recovery and examination of the cargo door, the Safety Board's original analysis and probable cause have been modified. This report incorporates these changes and supersedes NTSB/AAR-90/01. The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff."

Over a period of eleven years, from 1985 to 1996, there have been four early model Boeing 747 aircraft which have suffered fatal explosive decompressions in flight which were all initially attributed to 'bombs', one of which was United Airlines Flight 811 as reported by the surviving crew. Two of the accidents have since had a bomb explosion ruled out as the probable cause while one cause is in dispute as a bomb or not and one cause is stated to be 'an improvised explosive device' which may or may not be a bomb. All four flights were and are controversial. It is these four flights that in similar circumstances with similar aircraft that left similar evidence that has led this investigator to conclude that one similar probable cause is the same for four, , Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800, and that similar cause is the only confirmed and irrefutable probable cause: the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression refined to the locations as the midspan latches and the cause as faulty wiring or switch.

The implication of this conclusion is that there were never any bombs, or missiles, or center fuel tanks initially exploding in flight on the four flights but an event in each occurred which mimics those other explosions, that is, an explosive decompression after an inadvertently ruptured open forward cargo door in flight. An additional important implication is that the hazards still exist to this day and are a potential danger to the passengers flying in the five hundred early model Boeing 747s still in service.

2. Purpose of Part II Comparison to Similar Accidents:

This part shall evaluate the four fatal in-flight breakups of Boeing 747s using the cumulative evidence of seventeen years to sustain the matching pattern for all four of an explosion in the forward cargo compartment by a sudden ruptured opening of the forward cargo door in flight at one or both of the midspan latches probably caused by faulty wiring.

Specific data about the four early model Boeing 747s:

Air India Flight 182: Sequence in construction:#330, Construction Number 21473
Date completed: 19 June 78, Type Aircraft: B747-237B Type of wiring: Poly-X
(Raychem Corp), accident date: June 23 1985

Pan Am Flight 103: Sequence in construction: #15, Construction Number 19646,

Date completed: 25 Jan 70, Type Aircraft: B747-121 Type of wiring: Poly-X (Raychem Corp), accident date: 21 December 88

United Airlines Flight 811: Sequence in construction:#89, Construction Number 19875, Date completed: 20 Oct 70, Type Aircraft: B747-122 Type of wiring: Poly-X (Raychem Corp), accident date: 23 February 89

Trans World Airlines Flight 800: Sequence in construction:#153, Construction Number 20083, Date completed: 18 August 71, Type Aircraft: B747-131 Type of wiring: Poly-X (Raychem Corp), accident date: 17 July 96

Excerpts of official corroborative statements for background: Air India Flight 182

From: Report Of The Court Investigating Accident To Air India Boeing 747 Aircraft VT-EFO, "Kanishka" On 23rd June 1985

From Canadian Aviation Bureau Safety Board

Aviation Occurrence Air India Boeing 747-237b VT-EFO Cork, Ireland 110 Miles West 23 June 1985

Boeing 747-237B 'Kanishka' aircraft VT-EFO was manufactured by Messrs Boeing Company under Sl.No. 21473. The aircraft was acquired by Air India on 19th June, 1978. Initially, it came with the expert Certificate of Airworthiness No. E-161805. Subsequently, the Certificate of Airworthiness No. 1708 was issued by the Director General of Civil Aviation, India on 5th July, 1978. The C of A was renewed periodically and was valid up to 29th June, 1985. From the beginning of June, 1985, C of A renewal work of the aircraft was in progress. The aircraft had the Certificate of Registration No. 2179 issued by the DGCA on 5th May, 1978. The commercial flight of 'Kanishka' aircraft started on 7th July, 1978.

2.4.1.2 The aircraft was maintained by Air India following the approved maintenance schedules. It had logged 23634:49 hours and had completed 7525 cycles till the time of accident.

A. On the morning of 23rd June, 1985 Air India's Boeing 747 aircraft VT-EFO (Kanishka) was on a scheduled passenger flight (AI-182) from Montreal and was proceeding to London enroute to Delhi and Bombay. It was being monitored at Shannon on the Radar Scope. At about 0714 GMT it suddenly disappeared from the Radar Scope and the aircraft, which has been flying at an altitude of approximately 31,000 feet, plunged into the Atlantic Ocean off the south-west coast of Ireland at position latitude 51 degrees 3.6 minutes N and Longitude 12 degrees 49 minutes W. This was one of the worst air disasters wherein all the 307 passengers plus 22 crew members perished.

The Canadian Aviation Safety Board respectfully submits as follows:

4.1 Cause-Related Findings

1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.
2. The forward and aft cargo compartments ruptured before water impact.
3. The section aft of the wings of the aircraft separated from the forward portion before water impact.
4. There is no evidence to indicate that structural failure of the aircraft was the lead event in this occurrence.
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence

is not conclusive. However, the evidence does not support any other conclusion.' The Indian Kirpal Report: "3.4.6.60 The only conclusion which can, however, be arrived at is that the aircraft had broken in midair and that there has been a rapid decompression in the aircraft.' and 4.10 'After going through the entire record we find that there is circumstantial as well as direct evidence which directly points to the cause of the accident as being that of an explosion of a bomb in the forward cargo hold of the aircraft.'

Excerpts of official corroborative statements for background: Pan Am Flight 103

From: Air Accidents Investigation Branch Aircraft Accident Report No 2/90

1.6.1 Leading particulars Aircraft type: Boeing 747-121 Constructor's serial number: 19646

N739PA first flew in 1970 and spent its whole service life in the hands of Pan American World Airways Incorporated. Its Certificate of Airworthiness was issued on 12 February 1970 and remained in force until the time of the accident, at which time the aircraft had completed a total of 72,464 hours flying and 16,497 flight cycles.

The accident was notified to the Air Accidents Investigation Branch at 19.40 hrs on the 21 December 1988 and the investigation commenced that day. The aircraft, Flight PA103 from London Heathrow to New York, had been in level cruising flight at flight level 310 (31,000 feet) for approximately seven minutes when the last secondary radar return was received just before 19.03 hrs. The radar then showed multiple primary returns fanning out downwind. Major portions of the wreckage of the aircraft fell on the town of Lockerbie with other large parts landing in the countryside to the east of the town. Lighter debris from the aircraft was strewn along two trails, the longest of which extended some 130 kilometres to the east coast of England. The report concludes that the detonation of an improvised explosive device led directly to the destruction of the aircraft with the loss of all 259 persons on board and 11 of the residents of the town of Lockerbie.

Excerpts of official corroborative statements for background: United Airlines Flight 811:

From: National Transportation Safety Board
Washington, D.C. 20594

Aircraft Accident Report Explosive Decompression-- Loss Of Cargo Door In Flight
United Airlines Flight 811 Boeing 747-122, N4713U
Honolulu, Hawaii February 24, 1989

The accident airplane, serial No. 19875, registered in the United States as N4713U, was manufactured as a Boeing 747-122 transport category airplane by the Boeing Commercial Airplane Company (Boeing), Seattle, Washington, a Division of the Boeing Company. N4713U, the 89th B-747 built by Boeing, was manufactured in accordance with Federal Aviation Administration (FAA) type certificate No. A20WE, as approved on December 30, 1969. The airplane was certificated in accordance with the provisions of 14 CFR Part 25, effective February 1, 1965.

On February 24, 1989, United Airlines flight 811, a Boeing 747-122, experienced an explosive decompression as it was climbing between 22,000 and 23,000 feet after taking off from Honolulu, Hawaii, en route to Sydney, Australia with 3

flightcrew, 15 flight attendants, and 337 passengers aboard. The airplane made a successful emergency landing at Honolulu and the occupants evacuated the airplane. Examination of the airplane revealed that the forward lower lobe cargo door had separated in flight and had caused extensive damage to the fuselage and cabin structure adjacent to the door. Nine of the passengers had been ejected from the airplane and lost at sea.

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff.

Excerpts of official corroborative statements for background: Trans World Airlines Flight 800:

From: National Transportation Safety Board
Washington, D.C. 20594
Aircraft Accident Report
In-flight Breakup Over the Atlantic Ocean
Trans World Airlines Flight 800
Boeing 747-131, N93119
Near East Moriches, New York
July 17, 1996

The accident airplane, N93119, a 747-100 series airplane (model 747-131), serial number (S/N) 20083, was manufactured by Boeing in July 1971 and purchased new by TWA. The airplane was added to TWA's operating certificate on October 27, 1971, and, except for a 1-year period, was operated by TWA in commercial transport service until the accident occurred. According to TWA records, the accident airplane had 93,303 total hours of operation (16,869 flight cycles) at the time of the accident. The 747-100 is a low-wing, transport-category airplane that is about 225 feet long and 63 feet high (from the ground to the top of the vertical stabilizer), with a wingspan of about 195 feet.

On July 17, 1996, about 2031 eastern daylight time, Trans World Airlines, Inc. (TWA) flight 800, a Boeing 747-131, N93119, crashed in the Atlantic Ocean near East Moriches, New York. TWA flight 800 was operating under the provisions of Code of Federal Regulations Part 121 as a scheduled international passenger flight from John F. Kennedy International Airport (JFK), New York, New York, to Charles DeGaulle International Airport, Paris, France. The flight departed JFK about 2019, with 2 pilots, 2 flight engineers, 14 flight attendants, and 212 passengers on board. All 230 people on board were killed, and the airplane was destroyed. Visual meteorological conditions prevailed for the flight, which operated on an instrument flight rules flight plan.

The National Transportation Safety Board determines that the probable cause of the TWA flight 800 accident was an explosion of the center wing fuel tank (CWT), resulting from ignition of the flammable fuel/air mixture in the tank. The source of ignition energy for the explosion could not be determined with certainty, but, of the sources evaluated by the investigation, the most likely was a short circuit outside of the CWT that allowed excessive voltage to enter it through electrical wiring

associated with the fuel quantity indication system.

Excerpts of corroborative statements for background:
For Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800:

3. Premise Explanation: Explosion in the forward cargo compartment of explosive decompression caused by structural failure of ruptured open forward cargo door at one or both of the midspan latches caused by faulty electrical wiring:

Proponent: John Barry Smith

Analysis: To determine the pattern in early model Boeing 747 accidents that suffered breakups in flight, it was necessary to evaluate carefully all the official accident reports concerning them. A pattern was detected of similar significant evidence among only four of the many hull losses. It was very probable that one initial event by one cause was the reason for all four. The evidence is detailed below. There are many significant individual matches of evidence among each flight to each other. For instance, three flights had strange radar returns at event time but Air India Flight 182 was out of radar range and therefore there is no match for all, therefore the match is not included below. Only the matches for all four flights are listed below.

Matching Significant Circumstantial Evidence: The matching significant circumstantial evidence that follows is for all the four aircraft, Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800:

- A. All four aircraft had probable causes initially thought to be bomb explosions.
- B. All four aircraft had the probable cause of bomb explosion modified.
- C. All four aircraft had breakups in their airframes in a similar amidships location.
- D. All four aircraft had at least nine missing never recovered bodies.
- E. All four aircraft had passengers which showed explosive decompression type injuries and no injuries consistent with a detonation of a powerful bomb.
- F. All four aircraft experienced a sudden, loud, audible sound on the cockpit voice recorder at event start time.
- G. All four aircraft had the source of the sudden, loud, audible sound as a bomb explosion disputed and the source as an explosive decompression supported.
- H. All four aircraft had an abrupt power cut to the recorders immediately after the sudden, loud, audible sound.
- I. All four aircraft had an explosion in or adjacent to the forward cargo compartment.
- J. All four aircraft had similar shattered fuselage skin in and around the forward cargo door.
- K. All four aircraft had relatively mild damage on the port side of the nose forward of

the wing directly opposite the shattered zone around the forward cargo door at the same initial event time.

L. All four aircraft had similar damage to their airframe structures from inflight ejected debris.

M. All four aircraft had foreign object damage to engine number three.

N. All four aircraft had incomplete reports of the status of the forward cargo door, in particular, the status of the two midspan latches was omitted.

O. All four aircraft had similar debris patterns on the surface of the ground or sea bottom. (United Airlines Flight 811 had much lesser debris that still fell in the same pattern as the rest which was first items to leave the aircraft landed the closest to the initial event location.)

4. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had probable causes which were initially thought to be bomb explosions:

Air India Flight 182. Initial action was to speculate on explosive sabotage for the cause and immediately requisition the services of a specialist in the detection of explosives sabotage in aircraft wreckage.

Pan Am Flight 103: Within a few days items of wreckage were retrieved upon which forensic scientists found conclusive evidence of a detonating high explosive.

United Airlines Flight 811: The flight crew heard the explosion, checked the damage and reported to the tower a bomb had gone off in their aircraft.

Trans World Airlines Flight 800: Initial information led to consideration of the detonation of a high energy explosive device.

Excerpts of official corroborative statements to support the match that all four flights were thought initially to be 'bombs'.

Air India Flight 182

From the Indian Kirpal Report: Initial Action Taken by the Government of India 1.2.8 It was also being speculated that the accident may have occurred due to an explosion on board the aircraft. In order to see whether there was any evidence of an explosion which could be gathered from the floating wreckage which was being salvaged, the Government of India requisitioned the services of Mr. Eric Newton, a Specialist in the detection of explosives sabotage in aircraft wreckage.

Pan Am Flight 103

From Air Accidents Investigation Branch Aircraft Accident Report No 2/90 Synopsis: Within a few days items of wreckage were retrieved upon which forensic scientists found conclusive evidence of a detonating high explosive.

United Airlines Flight 811

From NTSB AAR 92/02 1.15 Survival Aspects: At 0210, the FAA notified the U.S. Coast Guard that a United Airlines, Inc., B-747, with a possible bomb on

board, had experienced an explosion and was returning to HNL.

Trans World Airlines Flight 800

From NTSB AAR 00/03 2.2.1 The In-Flight Breakup: On the basis of this initial information, investigators considered several possible causes for TWA flight 800s in-flight structural breakup: a structural failure and decompression; detonation of a high-energy explosive device, such as a bomb exploding inside the airplane or a missile warhead exploding upon impact with the airplane; and a fuel/air explosion in the center wing fuel tank (CWT). Several factors led to speculation that the accident might have been caused by a bomb or missile strike. These factors included heightened safety and security concerns because of the 1996 Olympics then being held in the United States, the fact that TWA flight 800 was an international flight, and the sudden and catastrophic nature of the in-flight breakup.

5. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had the original cause of bomb explosion modified.

Two flights, United Airlines Flight 811 and Trans World Airlines Flight 800, had the accident cause changed from 'bomb explosion' to other; one flight, Air India Flight 182, remained a bomb for the Indians and maybe a bomb by the Canadians, and one flight, Pan Am 103, became an "improvised explosive device" which may or may not be a bomb.

Air India Flight 182 is now stated to be an explosion from an unstated source by the Canadian aviation accident investigators and an explosion by bomb by the judicial inquiry of Judge Kirpal.

Pan Am Flight 103 is now stated to be an explosion by an 'an improvised explosive device', which may or may not be a 'bomb'. The British accident investigators could certainly have called the cause a 'bomb' if they had chosen to but declined as the evidence supported a conclusion of an improvised explosive device but did not support the conclusion of a 'bomb.' A cargo door has become an improvised explosive device in the United Airlines Flight 811 and the Paris Turkish Airlines DC-10 events in which tremendous explosions occurred by the inadvertently improvised complex door device. Firecrackers and fireworks illegally carried aboard in a cabin or cargo compartment can become inadvertent improvised explosive devices.

United Airlines Flight 811 is now stated to be an explosion by explosive decompression caused by an inadvertently opened forward cargo door in flight from defective electrical wiring or switch. After landing safely the crew and ground personnel discovered that the forward cargo door had opened in flight and there was no evidence of a bomb on board as they previously reported.

Trans World Airlines Flight 800 is now stated to be an explosion of the center fuel tank by an unknown ignition source but probably faulty wiring. NTSB concluded that the in-flight breakup of TWA flight 800 was not initiated by a bomb or a missile strike because of the lack of any corroboration evidence associated with a high energy explosion. A bomb explosion or missile strike was the official working explanation for seventeen months. Evidence of a detonating high explosive was discovered but determined to be benign such as a 'dog sniffing' test.

Excerpts of official corroborative statements that two of the aircraft changed their initial cause from 'bomb', one aircraft had explosion as a bomb or an explosion of unstated cause, and one aircraft had an explosion by an improvised explosive device.

Air India Flight 182

From the Canadian Aviation Occurrence Report: Canadian Aviation Safety Board respectfully submits as follows:

4.1 Cause-Related Findings 5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the evidence does not support any other conclusion.'

From the Kirpal Report: 4.10 After going through the entire record we find that there is circumstantial as well as direct evidence which directly points

to the cause of the accident as being that of an explosion of a bomb in the forward cargo hold of the aircraft. At the same time there is complete lack of evidence to indicate that there was any structural failure.

Pan Am Flight 103

From AAIB Aircraft Accident Report No 2/90: Synopsis. The report concludes that the detonation of an improvised explosive device led directly to the destruction of the aircraft with the loss of all 259 persons on board and 11 of the residents of the town of Lockerbie

United Airlines Flight 811:

From NTSB AAR 92/02: Executive Summary: The airplane made a successful emergency landing at Honolulu and the occupants evacuated the airplane. Examination of the airplane revealed that the forward lower lobe cargo door had separated in flight and had caused extensive damage to the fuselage and cabin structure adjacent to the door.

Trans World Air Airlines Flight 800

From NTSB AAR 00/03: 2.2.1.2 Consideration of a High-Energy Explosive Device Detonation (Bomb or Missile Warhead) Despite being unable to determine the exact source of the trace amounts of explosive residue found on the wreckage, the lack of any corroborating evidence associated with a high-energy explosion indicates that these trace amounts did not result from the detonation of a high-energy explosive device on TWA flight 800. Accordingly, the Safety Board concludes that the in-flight breakup of TWA flight 800 was not initiated by a bomb or a missile strike. The National Transportation Safety Board determines that the probable cause of the TWA flight 800 accident was an explosion of the center wing fuel tank (CWT), resulting from ignition of the flammable fuel/air mixture in the tank. The source of ignition energy for the explosion could not be determined with certainty,

6. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had breakups in their airframes in a similar amidships location.

For three of the aircraft the sudden huge hole appearing on the starboard side just forward of the wing was too large and the forward part of the aircraft pulled away from the aft part for a total breakup. United Airlines Flight 811 had a partial breakup with 'only' a ten foot by fifteen foot hole appearing and was able, with difficulty, to safely land soon after the explosive decompression when the forward cargo door opened in flight.

Air India Flight 182 had an inflight breakup when the aft part separated from the forward part.

Pan Am Flight 103 had an inflight breakup when the forward part pulled away from the rear part.

United Airlines Flight 811 had an inflight partial breakup of the forward part when a huge hole appeared in the nose of the aircraft.

Trans World Airlines Flight 800 had an inflight breakup when the nose portion pulled away from the rest of the aircraft.

Excerpts of official corroborative statements to support the match that all four flights had breakups in their airframes at a similar amidships location:

Air India Flight 182:

From the Canadian Aviation Occurrence Report: 3.3 Aircraft Break-up Sequence Hence, it is likely that the aft portion of the aircraft separated from the forward portion before striking the water. Canadian Aviation Safety Board Air India 23 June 1985, page 48

Pan Am Flight 103:

From AAIB Aircraft Accident Report No 2/90: 2.14 Summary The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage. UK AAIB Report 2/90 Page 56 The forward fuselage and flight deck area separated from the remaining structure within a period of 2 to 3 seconds." UK AAIB Report 2/90 Page 57 Although the pattern of distribution of bodies on the ground was not clear cut there was some correlation with seat allocation which suggested that the forward part of the aircraft had broken away from the rear early in the disintegration process. UK AAIB Report 2/90 Page 30

United Airlines Flight 811:

From NTSB AAR 92/02: 1.3 Damage to the Airplane The primary damage to the airplane consisted of a hole on the right side in the area of the forward lower lobe cargo door, approximately 10 by 15 feet large. An area of fuselage skin measuring about 13 feet lengthwise by 15 feet vertically, and extending from the upper sill of the forward cargo door, to the upper deck window belt, had separated from the airplane at a location above the cargo door extending to the upper deck windows. The floor beams adjacent to and inboard of the cargo door area had been fractured and buckled downward. NTSB/AAR 92/02 Page 4

Trans World Airlines Flight 800:

From NTSB AAR 00/03: 2.2.1.3 Consideration of a Fuel/Air Explosion in the Center Wing Fuel Tank It was clear from the wreckage recovery locations that the first pieces to depart the airplane were from the area in and around the airplane's wing center section (WCS), which includes the CWT, and, therefore, that the breakup must have initiated in this area.

7. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had at least nine never recovered bodies.

Extensive and long searches were made at the four accident sites soon after the events. The never recovered passengers were mostly those seated in the cabin near and above the forward

cargo door. One published report gives the macabre explanation for the missing bodies for United Airline Flight 811 as they were ingested into the adjacent number three engine.

Air India Flight 182 had 131 bodies recovered of the 329 which left 198 bodies never recovered with passengers assigned seats near and above the forward cargo compartment included in the missing.

Pan Am Flight 103 had ten passengers never recovered although evidence was presented of recovering very small items such as fragments of pieces of metal which indicates the extensive and thorough search that was conducted on land.

United Airlines Flight 811 had nine never recovered passengers, all expelled from the huge hole created when the forward cargo door opened in flight which took fuselage skin with it leaving the passengers above exposed. US Navy ships were on the scene very quickly but recovered no bodies.

Trans World Airlines Flight 800 has at least nineteen bodies never recovered although DNA testing of the fragments of bones identified all the passengers.

Excerpts of official corroborative statements to support the match that all four flights had at least nine missing, never recovered bodies.

Air India Flight 182

From the Canadian Aviation Occurrence Report: 3.1.6 In his testimony in Court, Wing Commander Dr. I.R. Hill further stated that the significance of flail injuries being suffered by some of the passengers was that it indicated that the aircraft had broken in mid-air at an altitude and that the victims had come out of the aeroplane at an altitude. He further explained that if an explosion had occurred in the cargo hold, it was possible that the bodies may not show any sign of explosion. It may here be mentioned that the forensic examination of the bodies do not disclose any evidence of an explosion. Furthermore, the seating pattern also shows that none of the bodies from Zone A or B was recovered, in fact as per the seating plan Zone B was supposed to have been unoccupied. This Zone is directly above the forward cargo compartment. Medical examination was conducted on the 131 bodies recovered after the accident. This comprises about 40 percent of the 329 persons on board. Canadian Aviation Safety Board Air India 23 June 1985, page 19

Pan Am Flight 103:

From AAIB Aircraft Accident Report No 2/90 1.13 Medical and pathological information The bodies of 10 passengers were not recovered and of these, 8 had been allocated seats in rows 23 to 28 positioned over the wing at the front of the economy section. UK AAIB Report 2/90 Page 31

United Airlines Flight 811

From NTSB AAR 92/02: Executive Summary: Nine of the passengers had been ejected from the airplane and lost at sea. 1.2 Injuries to Persons Injuries Flightcrew Cabincrew Passengers Others Serious Lost in flight. An extensive air and sea search for the passengers was unsuccessful. 1.15 Survival Aspects The fatal injuries were the result of the explosive nature of the decompression, which swept nine of the passengers from the airplane. The explosive decompression of the cabin when the cargo door separated caused the nine fatalities. The floor structure and

seats where the nine fatally injured passengers had been seated were subjected to the destructive forces of the decompression and the passengers were lost through the hole in the fuselage. Their remains were not recovered. Passengers-Nine Passengers who were seated in seats 8H, 9FGH, 10GH, 11GH and 12H, were ejected from the fuselage and were not found; and thus, are assumed to have been fatally injured in the accident.

Trans World Airlines Flight 800:

From NTSB AAR 00/03: 1.13 Medical and Pathological Information: Most identifications of occupants were accomplished through the use of fingerprints or dental records. However, in 29 cases, neither of these methods was successful; these cases required the use of deoxyribonucleic acid (DNA) protocols or forensic radiography as the primary means of identification. (Nineteen occupants were identified solely by DNA, and 10 were identified by forensic radiography, either by the medical examiner or the Armed Forces Institute of Pathology.)

8. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had passengers that showed explosive decompression type injuries and no evidence of bomb explosion injuries.

Air India Flight 182 has at least twenty five passengers who showed signs of decompression injuries and no evidence of bomb explosion injuries.

Pan Am Flight 103 had a majority of passengers who had been injured by the inflight disintegration of the aircraft and showed no evidence of bomb explosion injuries.

United Airlines Flight 811 had surviving passengers who suffered decompression type injuries such as baro trauma to the ear and no evidence of bomb explosion injuries.

Trans World Airlines Flight 800 had passengers who suffered from the effects of an inflight breakup of the aircraft and no evidence of bomb explosion injuries.

Excerpts of official corroborative statements to support the match that all four flights had passengers who suffered from decompression type injuries and no evidence of bomb explosion injuries.

Air India Flight 182

From the Canadian Aviation Occurrence Report: 2.9 Medical Evidence Flail pattern injuries were exhibited by eight bodies. Five of these were in Zone E, one in Zone D, two in Zone C and one crew member. The significance of flail injuries is that it indicates that the victims came out of the aircraft at altitude before it hit the water. There were 26 bodies that showed signs of hypoxia (lack of oxygen), including 12 children, 9 in Zones C, 6 in Zone D and 11 in Zone E. There were 25 bodies showing signs of decompression, including 7 children. Pathological examination failed to reveal any injuries indicative of a fire or explosion.

Pan Am Flight 103

From AAIB Aircraft Accident Report No 2/90 1.13 Medical and pathological information The results of the post mortem examination of the victims indicated that the majority had experienced severe multiple injuries at different stages, consistent with the in-flight disintegration of the aircraft and ground impact. There was no

pathological indication of an in-flight fire and no evidence that any of the victims had been injured by shrapnel from the explosion. There was also no evidence which unequivocally indicated that passengers or cabin crew had been killed or injured by the effects of a blast. Of the casualties from the aircraft, the majority were found in areas which indicated that they had been thrown from the fuselage during the disintegration. Although the pattern of distribution of bodies on the ground was not clear cut there was some correlation with seat allocation which suggested that the forward part of the aircraft had broken away from the rear early in the disintegration process. The bodies of 10 passengers were not recovered and of these, 8 had been allocated seats in rows 23 to 28 positioned over the wing at the front of the economy section.

United Airlines Flight 811

From NTSB AAR 92/02: Injury Information Passengers.--Nine Passengers who were seated in seats 8H, 9FGH, 10GH, 11GH, and 12H, were ejected from the fuselage and were not found; and thus, are assumed to have been fatally injured in the accident. Passengers seated in the indicated seats sustained the following injuries: Seat 7C Barotrauma to both ears 9E Superficial abrasions and contusions to the left hand, mild barotrauma to both ears 13D Barotrauma to both ears 13E Bleeding in both ears 14A Laceration in the parietal occipital area, barotrauma to both ears 16J Barotrauma to both ears 26A Barotrauma to both ears 26B Barotrauma to both ears 26H Barotitis to both ears, low back pain, irritation to the right eye due to foreign bodies 27A Barotrauma to the right ear 28J Superficial abrasions and a contusion to the left hand, mild barotrauma to both ears

Trans World Airlines Flight 800

From NTSB AAR 00/03: 1.13 Medical and Pathological Information A Medical Forensic Investigation Analysis Report, dated January 28, 1999, and prepared for the Department of Justice/FBI by a medical/forensic expert, 166 concluded the following: Exhaustive analysis of all available medical data on the victims of TWA Flight 800 by an experienced team of forensic pathologists, biomechanicists and criminal investigators failed to find any evidence that any victim was directly exposed to a bomb blast or missile warhead detonation. This finding makes it highly unlikely that a localized explosion occurred within the passenger cabin of TWA Flight 800. All injuries found in the victims were consistent with severe in-flight break up and subsequent water impact.

9. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had experienced a sudden, loud, audible sound on the cockpit voice recorder at event start time:

It is very unusual to have a sudden, loud, audible sound appear to the flightcrew in flight. It never happens under usual circumstances and only four times in accidents. The rarity and difficulty in creating such an event leads to the assumption that one identical initial event caused the sound which appeared on all four cockpit voice recorders, such as a bomb explosion, a center tank explosion, or an explosive decompression from a sudden hull rupture.

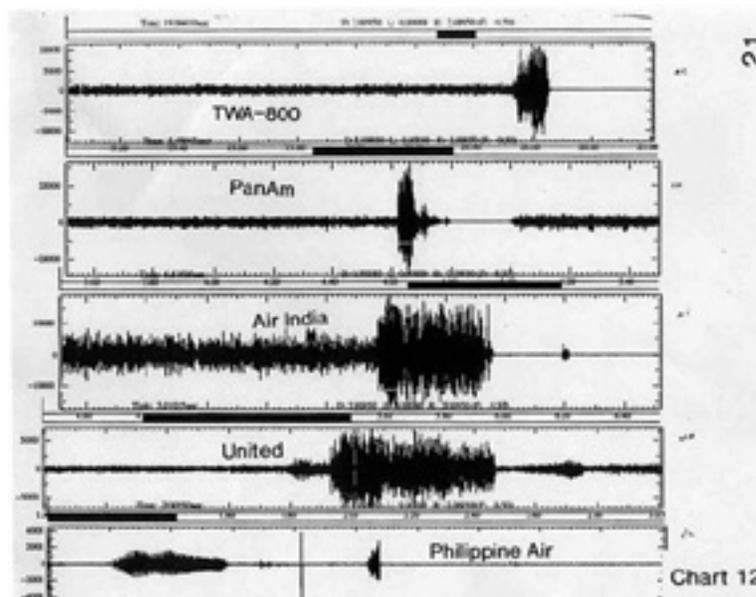
Air India Flight 182 was flying normally when a sudden, loud, audible sound occurred.

Pan Am Flight 103 was flying normally when a sudden, loud, audible sound occurred.

United Airlines Flight 811 was flying normally when a sudden, loud, audible sound occurred and described by a survivor as a 'tremendous explosion'.

Trans World Airlines Flight 800 was flying normally when a sudden, loud, audible sound occurred.

Excerpts of official corroborative statements to support the match that all four flights experienced a sudden, loud audible sound on the cockpit voice recorder at event start time.



Above Chart 12 from TWA 800 Public Docket for TWA 800 and shows CVR data for TWA 800, Pan Am Flight 103, Air India Flight 182, United Airlines Flight 811, and a Philippines Airlines 737.

Air India Flight 182:

From the Canadian Aviation Occurrence Report: 2.10.1 Analysis by National Research Council, Canada From the CVR and DFDR, AI 182 was proceeding normally en route from Montreal to London at an altitude of 31,000 feet and an indicated airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound. The sound continued for about 0.6 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder. Canadian Aviation Safety Board Air India 23 June 1985, page 21

Pan Am Flight 103:

From AAIB Aircraft Accident Report No 2/90 1.11.2 Cockpit voice recorder The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual crew behaviour. The tape record ended, at 19:02:50 hrs +/- second, with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording whilst the crew were copying their transatlantic clearance from Shanwick ATC." UK AAIB Report 2/90

Page 15 It is not clear if the sound at the end of the recording is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case. UK AAIB Report 2/90 Page 38

United Airlines Flight 811:

From NTSB AAR 92/02: 1.11 Flight Recorders The CVR revealed normal communication before the decompression. At 0209:09:2 HST, a loud bang could be heard on the CVR. The loud bang was about 1.5 seconds after a "thump" was heard on the CVR for which one of the flightcrew made a comment. They heard a sound, described as a "thump," which shook the airplane. They said that this sound was followed immediately by a "tremendous explosion." The airplane had experienced an explosive decompression. The electrical power to the CVR was lost for approximately 21.4 seconds following the loud bang. The CVR returned to normal operation at 0209:29 HST, and cockpit conversation continued to be recorded in a normal manner. NTSB Accident Report 92-02 Page 25.

Trans World Airlines Flight 800:

From NTSB AAR 00/03: 1. Factual Information 1.1 History of Flight The CVR then recorded a very loud sound for a fraction of a second (0.117 second) on all channels immediately before the recording ended. 1.11.1.2 Cockpit Voice Recorder-Related Airplane Tests As previously discussed in section 1.1, the CVR recorded an event (a very loud sound) that was about 40 percent louder than the previous signals during the last few tenths of a second of the CVR recording, which continued until the CVR recording abruptly stopped. The CVRs recovered from these airplanes all recorded very loud sound events just before they stopped recording. The sound signatures from these events were compared with the sound signatures recorded at the end of the TWA flight 800 CVR recording. Generally, the sound signatures could be characterized based on how quickly the loud noise event rose from the background noise (rise time), the duration of the loud noise event, and how quickly the loud noise event decreased (fall time). 121 The TWA flight 800 CVR recorded noise characteristics that were most similar to those recorded by the CVRs on board the United flight 811 and Philippine Airlines airplanes. At 2031:12, the CVR recording ended. A sound spectrum study of the information recorded by the CVR revealed that twice within the last second of the CVR recording (about 0.73 and 0.68 seconds before the recording stopped), the captain's channel recorded harmonic tones at the 400 Hertz 10 (Hz) frequency, but it did not record other electrical system background noise that it had recorded previously throughout the recording. These other electrical system background noises were recorded on the other CVR channels without interruption. 11 The CVR then recorded a every loud sound for a fraction of a second (0.117 second) on all channels immediately before the recording ended. The accident airplane's last recorded radar 12 transponder return occurred at 2031:12, and a review of the FDR data indicated that the FDR lost power at 2031:12.

10. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had the source of the sudden, loud, audible sound as a bomb explosion disputed and the source of the sudden, loud, audible sound as an explosive decompression supported.

Air India Flight 182:

The sudden loud, audible sound lacked certain low frequencies and had a slower rise time for it to be the sound of a bomb explosion. The sudden loud sound matched that of an explosive decompression of a wide body DC-10 decompression accident sound.

Pan Am Flight 103:

The sudden loud, audible sound did not match any bomb explosion sounds. The sound did match the sound of its structure breaking up.

United Airlines Flight 811

The sudden loud, audible sound did not match any bomb explosion sounds because a bomb explosion was conclusively ruled out. The sudden loud sound did match the sound of the explosive decompression when its forward cargo door opened in flight which allowed the inside compressed air to rush out suddenly into the low pressure outside air.

Trans World Airlines Flight 800

The sudden loud, audible sound did not match any bomb explosion sounds because a bomb explosion was conclusively ruled out. The sudden loud sound was matched to the sound of a Boeing 747 explosive decompression accident sound, specifically, United Airlines Flight 811.

Excerpts of official corroborative statements to support the match that all had the source of the sudden, loud, audible sound as a bomb explosion disputed and the source as an explosive decompression supported.

Air India Flight 182

From the Canadian Aviation Occurrence Report: 2.10.2 Analysis by Accidents Investigation Branch (AIB), United Kingdom An analysis of the CVR audio found no significant very low frequency content which would be expected from the sound created by the detonation of a high explosive device. Considering the different acoustic characteristics between a DC-10 and a B747, the AIB analysis indicates that there were distinct similarities between the sound of the explosive decompression on the DC-10 and the sound recorded on the AI 182 CVR. 3.4.6.52 It would be pertinent to note that even according to the report of Mr. Davis the rise time in the case of Kanishka, which has been given for the peak is about 40 milliseconds. 3.4.6.55 A reference may also be made, at this stage, the frequency spectrum of the sound of the hand gun which was fired on a Boeing 737 flight deck. He has stated that the rise time for reaching the peak is almost instantaneous. Same is the case with regard to the frequency spectrum prepared by him of a bomb in a B-737 aircraft where the bomb had been placed in the freight hold which is shown in Fig. 6. A perusal of that spectrum also shows that the peak was reached in approximately 5 ms. 3.4.6.57 The fact that a bang was heard is evident to the ear when the CVR as well as the ATC tapes are played. The bang could have been caused by a rapid decompression but it could also have been caused by an explosive device. One fact which has, however, to be noticed is that the sound from the explosion must necessarily emanate a few milliseconds or seconds earlier than the sound of rapid decompression because the explosion must necessarily occur before a hole is made, which results in decompression. In the event of there being an

explosive detonation then the sound from there must reach the area mike first before the sound of decompression is received by it. The sound may travel either through the air or through the structure of the aircraft, but if there is no explosion of a device, but there is nevertheless an explosive decompression for some other reason, then it is that sound which will reach the area mike. To my mind it will be difficult to say, merely by looking at the spectra of the sound, that the bang recorded on the CVR tape was from an explosive device.

Pan Am Flight 103

From AAIB Aircraft Accident Report No 2/90 2.3.2 Cockpit voice recorders The analysis of the cockpit voice recording, which is detailed in Appendix C, concluded that there were valid signals available to the CVR when it stopped at 19:02:50 hrs ± 1 second because the power supply to the recorder was interrupted. It is not clear if the sound at the end of the recording is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case.

United Airlines Flight 811

From NTSB AAR 92/02: 1.11 Flight Recorders Examination of the data plotted from the DFDR indicated that the flight was normal from liftoff to the accident. The recorder operated normally during the period. However, the decompression event caused a data loss of approximately 2 1/2 seconds. When the data resumed being recorded, all values appeared valid with the exception of the pitch and roll parameters. Lateral acceleration showed a sharp increase immediately following the decompression. Vertical acceleration showed a sharp, rapid change just after the decompression and a slight increase as the airplane began its descent. The CVR revealed normal communication before the decompression. At 0209:09:2 HST, a loud bang could be heard on the CVR. The loud bang was about 1.5 seconds after a "thump" was heard on the CVR for which one of the flightcrew made a comment. The electrical power to the CVR was lost for approximately 21.4 seconds following the loud bang. The CVR returned to normal operation at 0209:29 HST, and cockpit conversation continued to be recorded in a normal manner

Trans World Airlines Flight 800

From NTSB AAR 00/03: 1.11.1.2 Cockpit Voice Recorder-Related Airplane Tests Sound spectrum analysis plots from these airplane tests were compared with those from the TWA flight 800 CVR recording. For further comparisons, the Safety Board plotted the CVR recordings from other known in-flight explosions/breakups (such as Pan Am flight 103, a 747-100 airplane that crashed at Lockerbie, Scotland, after a bomb on board exploded; 117 an Air India 747-100 that crashed in the Atlantic Ocean southwest of Ireland after a bomb on board exploded; and United flight 811, a 747-100 that lost its forward cargo door in flight. The CVRs recovered from these airplanes all recorded very loud sound events just before they stopped recording. The sound signatures from these events were compared with the sound signatures recorded at the end of the TWA flight 800 CVR recording. Generally, the sound signatures could be characterized based on how quickly the loud noise event rose from the background noise (rise time), the duration of the loud noise event, and how quickly the loud noise event decreased (fall time). The TWA flight 800 CVR recorded noise characteristics that were most similar to those recorded by the CVRs on board the United flight 811 and Philippine Airlines airplanes.

11. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had an abrupt power cut to the data recorders immediately after a sudden, loud, audible sound at event start time.

It is very unusual to have an abrupt power cut to the data recorders in flight. It never happens under usual circumstances and only four times in accidents which were preceded by another rare occurrence, a sudden, loud, audible sound on the flightdeck. The rarity and difficulty in creating such an event leads to the assumption that one identical initial event caused the abrupt power cut which disrupted all four data recorders, such as a bomb explosion, a center tank explosion, or an explosive decompression from a sudden hull rupture

The actual duration or the fall time of the sudden loud sound can not be determined because the power to the recording device was severed before the sound ended. The sound may have lasted for quite a long time but it is not recorded. The duration of the sound and the fall time of it on the recorders is independent of the actual duration and fall time of the sudden loud sound.

Air India Flight 182 was proceeding normally until a sudden, loud, audible sound was immediately followed by an abrupt power cut to the data recorders.

Pan Am Flight 103 was proceeding normally until a sudden, loud, audible sound was immediately followed by an abrupt power cut to the data recorders.

United Airlines Flight 811 was proceeding normally until a sudden, loud, audible sound was immediately followed by an abrupt power cut to the data recorders.

Trans World Airlines Flight 800 was proceeding normally until a sudden, loud, audible sound was immediately followed by an abrupt power cut to the data recorders.

Excerpts of official corroborative statements to support the match that all four flights were proceeding normally until a sudden, loud, audible sound was immediately followed by an abrupt power cut to the data recorders.

Air India Flight 182

From the Canadian Aviation Occurrence Report: ' 2.10.1 Analysis by National Research Council, Canada From the CVR and DFDR, AI 182 was proceeding normally en route from Montreal to London at an altitude of 31,000 feet and an indicated airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound. The sound continued for about 0.6 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder. Canadian Aviation Safety Board Air India 23 June 1985, page 21 When synchronized with other recordings it was determined, within the accuracy that the procedure permitted, that the DFDR stopped recording simultaneously with the CVR. Canadian Aviation Safety Board Air India 23 June 1985, page 22

Pan Am Flight 103

From AAIB Aircraft Accident Report No 2/90 2.3.1 Digital flight data recordings The analysis of the recording from the DFDR fitted to N739PA, which is detailed in Appendix C, showed that the recorded data simply stopped. Following careful

examination and correlation of the various sources of recorded information, it was concluded that this occurred because the electrical power supply to the recorder had been interrupted at 19:02:50 +/- second. UK AAIB Report 2/90 Page 37 The analysis of the cockpit voice recording, which is detailed in Appendix C, concluded that there were valid signals available to the DVR when it stopped at 19:02.50 +/- second because the power supply to the recorder was interrupted. It is not clear if the sound at the end of the recording is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case. UK AAIB Report 2/90 Page 38

United Airlines Flight 811

From NTSB AAR 92/02: 1.11 Flight Recorders However, the decompression event caused a data loss of approximately 2 1/2 seconds. The CVR revealed normal communication before the decompression. At 0209:09:2 HST, a loud bang could be heard on the CVR. The loud bang was about 1.5 seconds after a "thump" was heard on the CVR for which one of the flightcrew made a comment. The electrical power to the CVR was lost for approximately 21.4 seconds following the loud bang. NTSB AAR 92/02. page 25

Trans World Airlines Flight 800:

From NTSB AAR 00/03: 1.11.2 Flight Data Recorder During the first 12 1/2 minutes of the accident flight (from the start of the takeoff roll until 2031:12, when the recording stopped abruptly), the FDR operated continuously and recorded data consistent with a normal departure and climb. The data indicated that the airplane was in a wings-level climb, and the vertical and longitudinal acceleration forces were consistent with normal airplane loads when the recording stopped. Examination of the FDR data revealed that the interruption of the recording at 2031:12 was consistent with the loss of electrical power to the recorder. 1.1 History of Flight At 2031:12, the CVR recording ended. The CVR then recorded a every loud sound for a fraction of a second (0.117 second) on all channels immediately before the recording ended. The accident airplane's last recorded radar 12 transponder return occurred at 2031:12, and a review of the FDR data indicated that the FDR lost power at 2031:12.

12. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had an explosion in or adjacent to the forward cargo compartment.

Air India Flight 182 had an explosion in the forward cargo compartment.

Pan Am Flight 103 had an explosion in the forward cargo compartment.

United Airlines Flight 811 had an explosion in the forward cargo compartment.

Trans World Airlines Flight 800 had an explosion in the center fuel tank immediately adjacent to the forward cargo compartment with much tangible evidence of an explosion in the forward cargo compartment as the initial event and the center tank explosion later as a consequence.

Excerpts of official corroborative statements to support the match that all four flights had an explosion in or adjacent to the forward cargo compartment.

Air India Flight 182:

From the Canadian Aviation Occurrence Report: 4.1 Cause-Related Findings "There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment." Canadian Aviation Safety Board Air India 23 June 1985, page 58

Pan Am Flight 103:

From AAIB Aircraft Accident Report No 2/90 1.12.2.4 Baggage containers It was evident, from the main wreckage layout, that the explosion had occurred in the forward cargo hold and, although all baggage container wreckage was examined, only items from this area which showed the relevant characteristics were considered for the reconstruction. The initial explosion triggered a sequence of events which effectively destroyed the structural integrity of the forward fuselage. UK AAIB Report 2/90 Page 43 The direct explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. UK AAIB Report 2/90 Page 56

United Airlines Flight 811:

From NTSB AAR 92/02: 1.6.2 Cargo Door Description and Operation Both the forward and aft lower cargo doors are similar in appearance and operation. They are located on the lower right side of the fuselage and are outward-opening. The door opening is approximately 110 inches wide by 99 inches high, as measured along the fuselage. 1.3 Damage to the Airplane The primary damage to the airplane consisted of a hole on the right side in the area of the forward lower lobe cargo door, approximately 10 by 15 feet large. The cargo door fuselage cutout lower sill and side frames were intact but the door was missing (see figures 1 and 2). An area of fuselage skin measuring about 13 feet lengthwise by 15 feet vertically, and extending from the upper sill of the forward cargo door to the upper deck window belt, had separated from the airplane at a location above the cargo door extending to the upper deck windows. The floor beams adjacent to and inboard of the cargo door area had been fractured and buckled downward. Executive Summary The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression.

Trans World Airlines Flight 800:

NTSB AAR 00/03 Executive Summary: The National Transportation Safety Board determines that the probable cause of the TWA flight 800 accident was an explosion of the center wing fuel tank (CWT), resulting from ignition of the flammable fuel/air mixture in the tank. The source of ignition energy for the explosion could not be determined with certainty, but, of the sources evaluated by the investigation, the most likely was a short circuit outside of the CWT that allowed excessive voltage to enter it through electrical wiring associated with the fuel quantity indication system. From NTSB TWA 800 Photographs and text from Public Docket No. SA-516, Exhibit No. 18A, Sequencing Study, page 20, "Downward separation directions were noted at STA 900, 880, 840, 820, 800, and 780...The initial opening of the fuselage lower lobe (e.g. LF6A) would have the expected

result of rapid depressurization accompanied by collapse of the main deck floor for some distance forward of STA 1000. The red area recovery of interior components as far forward as STA 600 would not be inconsistent with this floor collapse and associated structural breakup."

13. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had similar shattered fuselage skin in and around the forward cargo door.

The forward cargo doors of Pan Am Flight 103 and Air India Flight 182, are shown in drawings as equally split longitudinally which matches the retrieved United Airlines Flight 811 forward cargo door longitudinal split of its retrieved forward cargo door. The Trans World Airlines Flight 800 forward cargo door is shown in photographs as very shattered with two ruptures of outward peeled skin at each midspan latch.

The text description of the damage of the Air India Flight 182 forward cargo door and the surrounding area fits very closely with the photographs of the forward cargo door and the surrounding area of Trans World Airlines Flight 800, a Boeing 747 that also suffered an inflight breakup in flight thought to be caused by a bomb explosion in the forward cargo compartment. Photographs of the forward cargo door area of Trans World Airlines Flight 800 with the closeup of the forward cargo door area demonstrate the shattered destruction of the door area. The text from the Indian Kirpal report concerning pieces of wreckage debris around the forward cargo door of Air India Flight 182 describes very accurately the details in the photographs of the same area of Trans World Airlines Flight 800. The matches of both cargo door areas to each other with similar holes, flaps, fractures, inward concavity, tears, deformities, outward bent petals, curls, missing pieces, cracks, separations, curved fragments, spikes, and folds are apparent by matching the photographs of Trans World Airlines Flight 800 to the text of Air India Flight 182. There are no photographs yet available of the forward cargo door area of Air India Flight 182 in the accident reports to compare to the other three aircraft.



Above/previous page is a NTSB photograph of the wreckage reconstruction of Trans World Airlines Flight 800 starboard side over and forward of the wing. Fuselage station 600 is to the right extending to fuselage station 960 to the left in the photograph. A little over half of the forward cargo door is the shattered area in the lower right hand section. An outward opening petal shaped rupture can be seen at the aft midspan latch of the forward cargo door. The mildly damaged right hand, number two passenger door is in the middle left of the photograph.



Above is a closeup photograph of about a half of the Trans World Airlines Flight 800 forward cargo door extending from fuselage station 520 on the right to fuselage station 620 to the left in the photograph. The cargo door hinge is in red near the top of the photograph. The outward opening petal shaped oval rupture is located at the forward midspan latch of the forward cargo door.

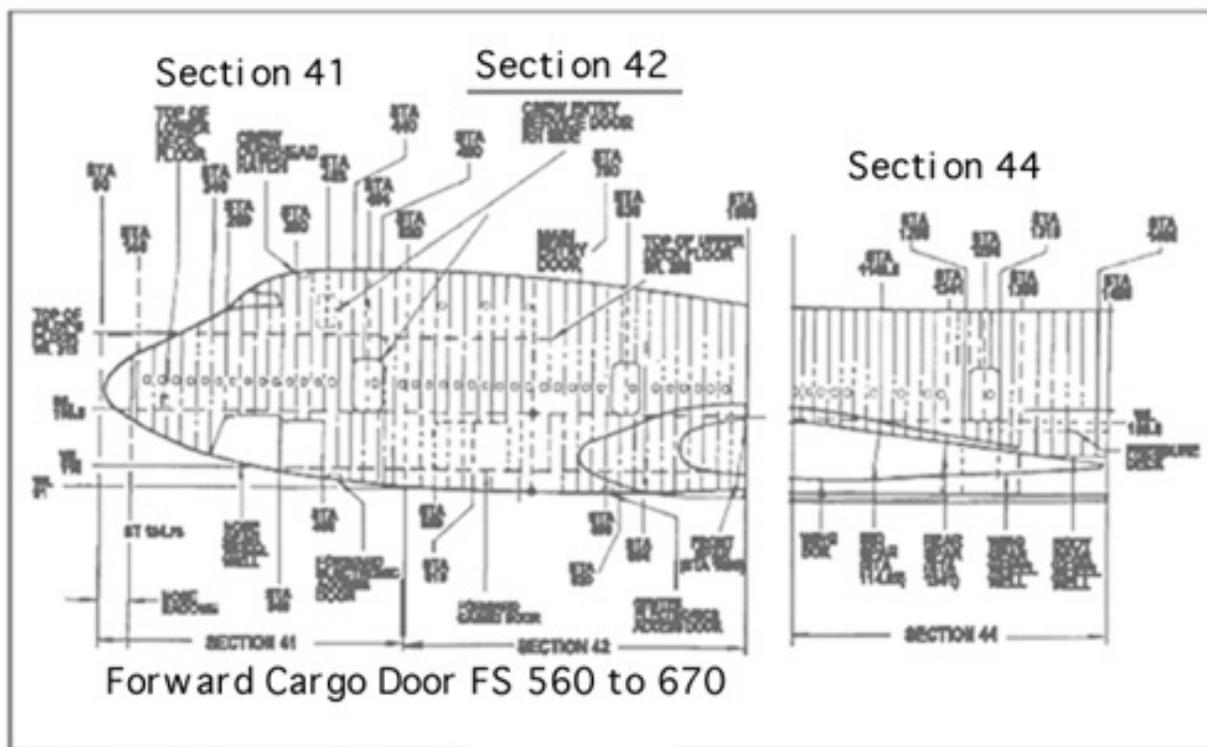


Figure 3a. Locator of fuselage sections 41, 42, and 44.

Above is a drawing from NTSB AAR 00/03 showing fuselage station numbers and sections.

Below is text from the Canadian Aviation Occurrence Report and the Indian Kirpal Report referring to Air India Flight 182 area forward of the wing on the starboard side:

E. Damage in air : The cargo door of the front cargo compartment was also found ruptured from above.

2.11.4.6 Section 42 Portions of section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers. All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed.

3.2.11.23 Target 399 - Fuselage around 2R Door This target is shown in Fig. 399-1. A detailed description is given below : TARGET 399 Fuselage Station 780 to 940 in the longitudinal direction and stringer 7R down to stringer 35R circumferentially. This piece contained five window frames, one in the 2R

passenger entry door. Three of the window frames, including the door window frame, still contained window panes. Little overall deformation was found in the stringers and skin above the door. The structure did contain a significant amount of damage and fractures in the skin and stringers beneath the window level. In the area beneath the level of the windows, the original convex outward shape of the surface had been deformed into an inward concave shape. Further inward concavity was found in the skin between many of the stringers below stringer 28R. The skin at the forward edge of the piece was folded outward and back between stringers 25R and 30R. Over most of the remaining edges of the piece a relatively small amount of overall deformation was noted in the skin adjacent to the edge separations. Twelve holes or damage areas were numbered and are further described.

No.1 : Hole, 5 inches by 9 inches with two large flaps and one smaller curl, all folded outward. Reversing slant fractures, small area missing.

No.2 : Hole, 2 inches by 3/4 inch, one flap folded outward, reversing slant fractures, one curled sliver, no missing metal.

No.3 : Triangular shaped hole about 2 inches on each side. One flap, folding inward, with one area with a serrated edge. No missing metal, extensive cracking away from corners of the hole, reversing slant fracture.

No.4 : Tear area, 8 inches overall, with deformation inward in the centre of the area. Reversing slant fracture.

No.5 : Fracture area with two legs measuring 14 inches and about 24 inches. Small triangular shaped piece missing from a position slightly above stringer 27R. Inward fold noted near the joint of the legs. An area of 45^o scuff marks extend onto this fold.

No.6 : Hole about 2.5 inches by 3 inches with a flap folded outward, reversing slant fracture. Approximately half the metal from the hole is missing.

No.7 : Hole about 3 inches by 1 inch, all metal from the hole is missing. Fracture edges are deformed outward.

No.8 : Forward edge of the skin is deformed into an "S" shaped flap. Three inward curls noted on an edge.

No.9 : Inwardly deformed flap of metal between stringers 11R and 12R at a frame splice separation. No evidence of an impact on the outside surface.

No.10 : Door lower sill fractured and deformed downward at the aft edge of the door.

No.11 : Frame 860 missing above stringer 14R. Upper auxiliary frame of the door has its inner chord and web missing at station 860. A 10 inch piece of stringer 12R is missing aft of station 860.

No.12 : Attached piece of floor panel (beneath door) has one half of a seat track attached. The floor panel is perforated and the lower surface skin is torn.

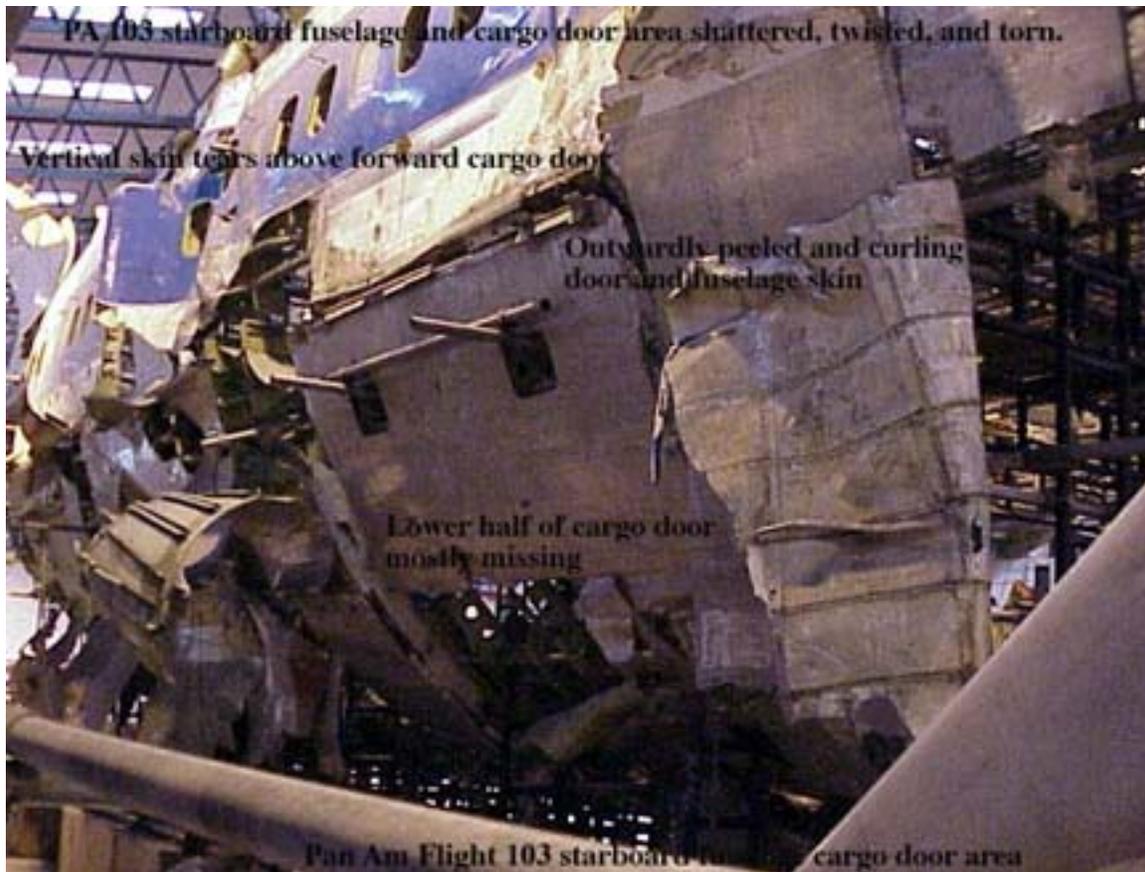
3.2.11.28 Target 362/396 Forward Cargo Skin This piece included the station 815 electronic access door, portions of seven longitudinal stringers to the left of bottom centre and five longitudinal stringers to the right of bottom centre. The original shape of the piece (convex in the circumferential direction) had been deformed to a concave inward overall shape. Multiple separations were found in the skin as well as in the underlying stringers. Further inward concavity was found in the skin between most of the stringers.

3.2.11.29 The two sides of this piece are shown in Fig. 362-1 and 362-2. This piece has 25 holes or damaged areas in most of which there are multiple petals curling outwards. These holes are numbered 1 to 3, 4a, 4b, 4c and 5 to 23. These are described below. Unless otherwise noted, holes did not have any material missing :

- No.1 : Hole with a large flap of skin, reversing slant fracture.
- No.2 : Hole with multiple curls, reverse slant fracture.
- No.3: Hole with multiple flaps and curls, reversing slant fracture, one area of spikes (ragged sawtooth)
- No.4A: One large flap, reverse slant fracture, one area of spikes.
- No.4B : Hole with two flaps.
- No.4C : Hole with two flaps, one area of spikes
- No.5 : Hole with two flaps
- No.6 : Branching tear from the left side of the piece, reversing slant fracture.
- No.7 : Hole, with one flap, one curl and one area of spikes.
- No.8: Very large tear from the left side of the piece with multiple flaps and curls, reversing slant fracture and at least two areas of spikes.
- No.9 : Hole with multiple flaps, one curl.
- No. 10: 2.5 inch tear
- No.11: One flap
- No. 12: Grip hole, plus a curl with spikes on both sides of the curl.
- No.13: "U" shaped notch with gouge marks in the inboard/outboard direction. Three curls are nearby with one are of spikes. Gouges found on a nearby stringer and on a nearby flap.
- No. 14 : Nearly circular hole, 0.3 inch to 0.4 inch in diameter. Small metal lipping on outside surface of the skin. Most of the metal from the hole is missing.
- No. 15 : Hole in the skin beneath the first stringer to the left of centre bottom. Small piece missing.
- No. 16 : Hole in the stringer above hole No. 15. Most of the metal from this hole is missing.
- No. 17 : Hole through the second stringer to the left of centre bottom, 0.4 inch in diameter. The hole encompassed a rivet which attached the stringer to the outer skin. Small pieces of metal missing.
- No. 18 : Hole at the aft end of the piece between the third and fourth stringers to the left of centre bottom. The hole consisted of a circular portion (0.4 inch diameter), plus a folded lip extending away from the hole. The metal from the circular area was missing.
- No. 19 : Hole with metal folded from the outside to the inside, about 0.6 inch by 1.5 inch. Flap adjacent to the hole contained a heavy gouge mark on the outside surface of the skin.
- No. 20 : Hole containing a piece of extruded angle.
- No. 21 : Hole containing a piece of extruded angle.
- No. 22 : Hole with one flap.
- No. 23 : Hole about 0.3 inch in diameter, with tears away from the hole. Small piece missing.

Air India Flight 182 forward cargo door was ruptured, split and shattered.

Pan Am Flight 103 has no text information about the forward cargo door although it was near the location of the explosion in the forward cargo compartment. The reconstruction drawing shows the forward cargo door split longitudinally at the midspan latches at the initial event start time.

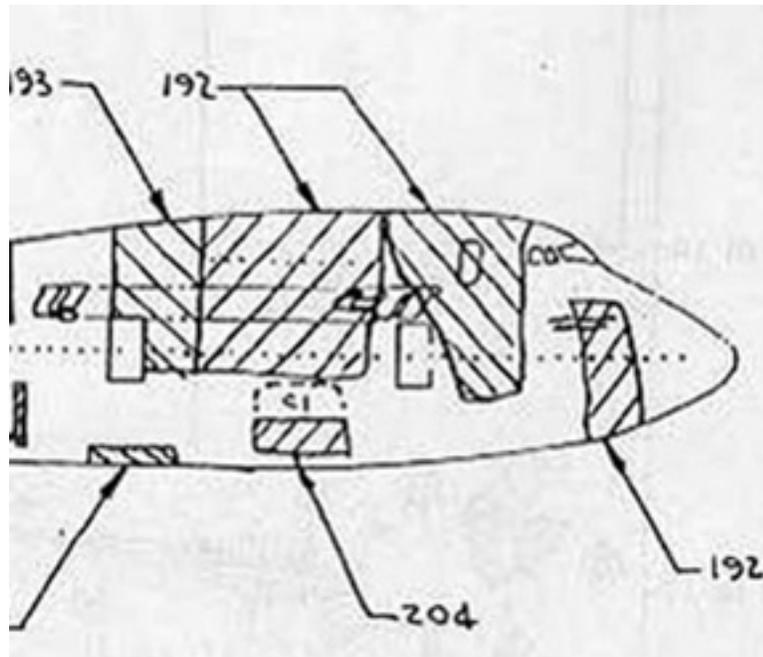


Above AAIB photograph of forward cargo door area of Pan Am Flight 103 shows the peeled back skin, vertical tear lines, and general shattered appearance.

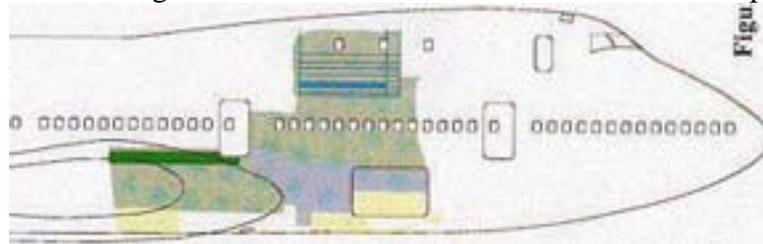
United Airlines Flight 811 gives a detailed report on the ruptured and split forward cargo door.

Trans World Airlines Flight 800 photographs show the ruptured, split and shattered forward cargo door.

Excerpts of official corroborative drawings and photographs to support all aircraft had similar shattered skin in and around the forward cargo door.
Air India Flight 182 from the Indian Kirpal Report:



Pan Am Flight 103 below from AAIB Aircraft Accident Report No 2/90



United Airlines Flight 811 below from NTSB AAR 92/02

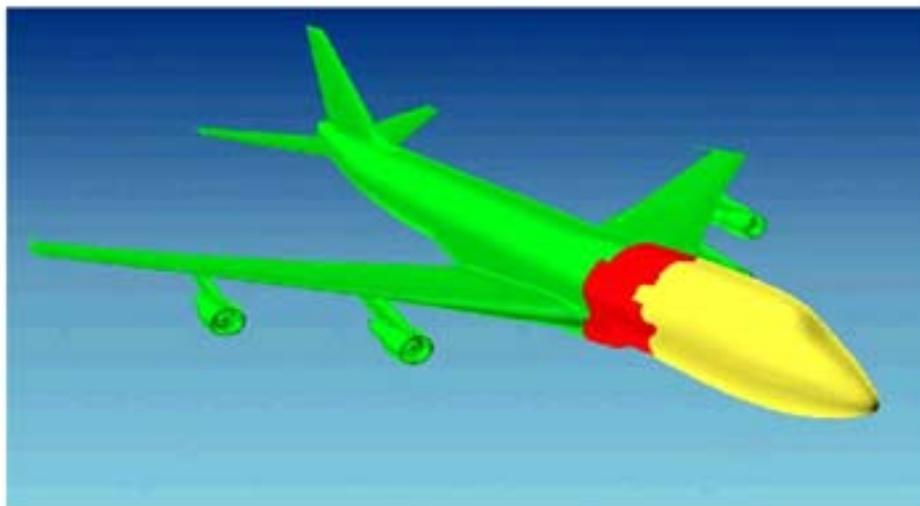


Figure 1.--Overall view of forward cargo door area on the right side of the aircraft.

Trans World Airlines Flight 800 below from NTSB public docket and AAR 00/03:



Below illustration shows the red zone of Trans World Airlines Flight 800 which is were all the first debris left the aircraft. The red zone includes the forward cargo door area but the zone is forward of the center fuel tank.



14. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had relatively mild damage on the port side of the nose forward of the wing directly opposite the shattered zone around the forward cargo door at the same initial event time.

Air India Flight 182 concentrated on the starboard side since it had unusual damage on the fuselage wreckage. No photographs are yet available of the port side. There is no report of any damage on the port side of the aircraft. Only a few parts of the port side were retrieved and nothing unusual was reported about those pieces.

Pan Am Flight 103 had large areas of skin torn away on the starboard side during the first instants of the initial event while immediately opposite at the same time only a few pieces were torn off.

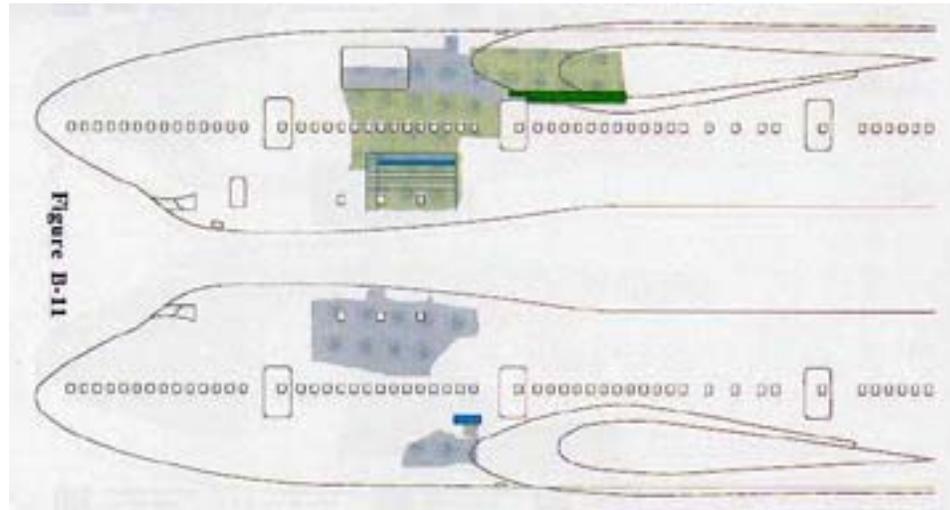
United Airlines Flight 811 had no damage to the port side of the airframe. All of the damage was on the starboard side from the explosive decompression and the ejected objects. The vertical stabilizer in the middle of the aircraft was damaged.

Trans World Airlines Flight 800 had no inflight damage on the port side while the starboard side directly opposite is shattered and torn.

Excerpts of official corroborative statements to support the match that all four flights had relatively mild damage on the port side of the nose forward of the wing directly opposite the shattered zone around the forward cargo door at the same initial event time.

Air India Flight 182: From the Indian Kirpal Report and the Canadian Aviation Occurrence Report: Five frames and door-port side aft# 5 left door (iii) Section of fuselage between B S 510 to B S 700, including the passenger window belt right side, up and over crown to include upper deck windows left side (Target No. 218). (iv) Section of fuselage between B S 720 to B S 840 including left side passenger window belt, up and over crown to right side passenger window belt. Forward and upper edges of L H No.2 door cutout can be seen (Target No. 193). (v) Large section of fuselage between B S 1000 to B S 1460 including left side passenger window belt, up and over crown to right side passenger window belt. This section was found lying on its right side (Target No. 137). There was no reported in flight damage to engines Nos. 1 and 2.

Pan Am Flight 103: From UK AAIB Report 2/90



Above drawing from Figure B-11 of the AAIB report shows the large amounts of fuselage skin around the forward cargo door (top drawing) torn away at initial event time while on the port side (bottom drawing) at the same time, only a few pieces are torn off. The dark blue rectangle is the very small 'bomb explosion' shatter zone which is purported to have caused the aircraft to break in two.

United Airlines Flight 811: From NTSB AAR 92/02: 1.3 Damage to the Airplane
 The primary damage to the airplane consisted of a hole on the right side in the area of the forward lower lobe cargo door, approximately 10 by 15 feet large. The cargo door fuselage cutout lower sill and side frames were intact but the door was missing (see figures 1 and 2). An area of fuselage skin measuring about 13 feet lengthwise by 15 feet vertically, and extending from the upper sill of the forward cargo door to the upper deck window belt, had separated from the airplane at a location above the cargo door extending to the upper deck windows. The floor beams adjacent to and inboard of the cargo door area had been fractured and buckled downward. Examination of all structure around the area of primary damage disclosed no evidence of preexisting cracks or corrosion. All fractures were typical of fresh overstress breaks. Debris had damaged portions of the right wing, the right horizontal stabilizer, the vertical stabilizer and engines Nos. 3 and 4. No damage was noted on the left side of the airplane, including engines Nos. 1 and 2.

Trans World Airlines Flight 800: From NTSB Public Docket photograph



Above photograph shows the smooth port side forward of the wing (nose to left in photograph), while directly opposite the starboard side is shattered and torn. There was no inflight damage to engines Nos. 1 or 2, both on the port side of the aircraft.

15. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had similar damage to their airframe structures from inflight ejected debris.

Air India Flight 182 had inflight damage to the right wing root, number three engine and cowling, engine number four cowling, vertical stabilizer, and the right horizontal stabilizer.

Pan Am Flight 103 had inflight damage to number three engine and cowling, the vertical stabilizer, and the right horizontal stabilizer. The wing was destroyed and examination for inflight damage was not possible.

United Airlines Flight 811 had inflight damage to the leading edge of the right wing, engine number three and cowling, engine number four and cowling, the vertical stabilizer, the right horizontal stabilizer.

Trans World Airlines Flight 800 had inflight damage to the right wing, engine number three and cowling, and the right horizontal stabilizer.

Excerpts of official corroborative statements to support the match that all four flights had similar inflight damage to their airframe structures.

Air India Flight 182:

From the Canadian Aviation Occurrence Report 3.4.1 Aircraft Break-up The examination of the floating wreckage indicates that the right wing root leading edge, the number 3 engine inboard fan cowling, the right inboard midflap leading edge, and the right horizontal stabilizer root leading edge all exhibit damage consistent with objects striking the right wing and stabilizer before water impact. page 49. The fan cowls of the number 4 engine show evidence of being struck by a portion of the turbine from number 3 engine. page 49 The right wing root fillet which faired the leading edge of the wing to the fuselage ahead of the right spar had a vertical dent similar to that which would have resulted had the fillet run into a soft cylindrical

object with significant relative velocity. page 30. The fan cowls of the number 4 engine had a series of five marks in a vertical line across the centre of the Air India logo on the inboard facing side of the fan cowl. These marks had the characteristic airfoil shape of a turbine blade tip. It is possible that a portion of the turbine parted from the number 3 engine and struck the cowl of the number 4 engine.

Pan Am Flight 103:

UK AAIB Report 2/90 1.14 Fire Of the several large pieces of aircraft wreckage which fell in the town of Lockerbie, one was seen to have the appearance of a ball of fire with a trail of flame. Its final path indicated this was the No 3 engine, which embedded itself in a road in the north-east part of the town. page 31 During this process the lower nose section struck the No 3 engine intake causing the engine to detach from its pylon. This fuselage separation was apparently complete within 3 seconds of the explosion. page 44. Containers and items of cargo ejected from the fuselage aperture in the forward hold, together with pieces of detached structure, collided with the empennage severing most of the left tailplane, disrupting the outer half of the right tailplane, and damaging the fin leading edge structure. page 57 Examination of the structure of the fin revealed evidence of in-flight damage to the leading edge caused by the impact of structure or cabin contents. 1.12.3.3 General damage features not directly associated with explosive forces. (v) A large, clear, imprint of semi-elliptical form was apparent on the lower right side at station 360 which had evidently been caused by the separating forward fuselage section striking the No 3 engine as it swung rearwards and to the right (confirmed by No 3 engine fan cowl damage)

United Airlines Flight 811:

From NTSB AAR 92/02: 1.3 Damage to the Airplane The primary damage to the airplane consisted of a hole on the right side in the area of the forward lower lobe cargo door, approximately 10 by 15 feet large. The cargo door fuselage cutout lower sill and side frames were intact but the door was missing. An area of fuselage skin measuring about 13 feet lengthwise by 15 feet vertically, and extending from the upper sill of the forward cargo door to the upper deck window belt, had separated from the airplane at a location above the cargo door extending to the upper deck windows. The floor beams adjacent to and inboard of the cargo door area had been fractured and buckled downwards. Debris had damaged portions of the right wing, the right horizontal stabilizer, the vertical stabilizer and engines Nos.3 and 4. The right wing had sustained impact damage along the leading edge between the No. 3 engine pylon and the No. 17 variable camber leading edge flap. Slight impact damage to the No. 18 leading edge flap was noted. The external surfaces of the No. 3 engine inlet cowl assembly exhibited foreign object damage including small tears, scuffs and a large outwardly directed hole. The entire circumference of all the acoustic (sound attenuator) panels installed on the inlet section of the cowl had been punctured, torn, or dented. The leading edges of all fan blade airfoils on the No. 3 engine exhibited extensive foreign object damage. External damage to the No 4 engine inlet and core cowls was confined to the inboard side of the inlet cowl assembly. The No. 4 engine fan blade airfoils had sustained both soft and hard object damage from foreign objects. NTSB/AAR 92/02 Page 7 NTSB/AAR 92/02 Page 8

Trans World Airlines Flight 800:

From NTSB TWA 800 Public Docket Exhibit 7A 3.1 Right Wing The right wing

had separated into two major sections. The wing structure between the inboard and outboard sections (WS 1224 to WS 1482) had broken into several pieces. Fire and soot damage was observed mainly on the inboard wing section, with some limited fire and soot damage on the other pieces. Docket No. SA-516, Exhibit No. 7A, Structures Group Report, page 33: 5.1 Horizontal Stabilizer, Some of the items found in the horizontal stabilizer are sections of seat track, a stator blade from turbine section, and glitter. On 5.1.1 Right Horizontal Stabilizer, page 34, An engine stator blade from turbine section penetrated the upper honeycomb surface near the outboard trailing edge.

16. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had foreign object damage to engine number three.

Engine number three is the engine closest to the fuselage on the starboard side and the engine closest to the forward cargo door. Any debris ejected from a sudden opening in the forward cargo compartment or cabin nearby will be ingested into the large fan of the engine. Foreign object damage to an engine inflight generally results in fire and bent or broken fan turbine blades. Sufficient ingestion of objects may result in an uncontainment where parts of the engine depart the nacelle and sometimes strike other parts of the aircraft such as the adjacent number four engine and cowling or the right horizontal stabilizer. Engine number three is directly in front of the right wing leading edge, the right wing fillet, and the right horizontal stabilizer.

Air India Flight 182 examination showed that an internal turbine part of engine number three departed and impacted the adjacent engine.

Pan Am Flight 103 examination showed engine number three ingested debris from within the aircraft.

United Airlines Flight 811 examination showed engine number three exhibited extensive foreign object damage.

Trans World Airlines Flight 800 examination showed that engine number three had many fan blades missing, soft body impacts on a partial airfoil, impact damage to the leading and trailing edges of the fan blades, and fan blade airfoils were bent rearward and the tips were bent forward. Foreign object damage is a cause for those damages.

Excerpts of official corroborative statements to support the match that all four flights had foreign object damage to engine number three.

Air India Flight 182:

From the Canadian Aviation Occurrence Report: The fan cowls of the number 4 engine show evidence of being struck by a portion of the turbine from number 3 engine. page 49 These marks had the characteristic airfoil shape of a turbine blade tip. It is possible that a portion of the turbine parted from the number 3 engine and struck the cowl of the number 4 engine.

Pan Am Flight 103:

UK AAIB Report 2/90 1.12.4 Examination of engines (ii) No 3 engine, identified on site as containing ingested debris from within the aircraft, nonetheless had no evidence of the type of shingling seen on the blades of No 2 engine.

United Airlines Flight 811: From NTSB AAR 92/02: 1.3 Damage to the Airplane
The leading edges of all fan blade airfoils on the No. 3 engine exhibited extensive foreign object damage.

Trans World Airlines Flight 800:

From NTSB TWA 800 Public Docket Exhibit 8A, Page 11, paragraph 3, discussing results of engine 3 disassembly: Of the 46 fan blades in the fan rotor, 21 blades with complete or partial airfoils and 6 root sections were recovered. All of the fan blades had sooting on the convex airfoil surfaces. Most of the full length airfoils were bent rearward and the tips outboard of the outer midspan shroud were bent forward slightly. About half of the fan blades had impact damage to the leading and trailing edges. Almost all of the impact damage to the airfoils could be matched to contact with the midspan shroud on an adjacent blade. One full length blade had four soft body impacts along the leading edge and a partial airfoil had a soft body impact, which had some streaking extending rearward.

17. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 had incomplete reports of the status of the forward cargo door.

In particular, the status of the two midspan latches of the forward cargo door is omitted even though the door is close to the site of the initial explosion and the latched status of the other doors is usually given. There is evidence of ruptures at the midspan latches of all the forward cargo doors. There are two identically sized cargo doors on Boeing 747s with twenty latches and sixteen locking sectors. There are two midspan latches for each door. The aft cargo door, the bulk cargo door, and the CRAF door is often reported as intact and latched. The eight midspan latches for the forward cargo doors on the four accident aircraft have not been discovered, nor retrieved, nor examined, nor evaluated, nor status reported. The whereabouts of those eight midspan latches in the four forward cargo doors is a mystery.

Air India Flight 182 forward cargo door was shattered with no status reported for any of the ten latches yet the aft cargo door was intact and latched at the bottom. There is a description and drawing of a longitudinal split of the forward cargo door near the midspan latches.

Pan Am Flight 103 omitted the latch status of the forward cargo door which was split in two while the aft cargo door (frames 1800-1920) is reported as latched. A reconstruction drawing shows a longitudinal split at the midspan latches of the forward cargo door.

United Airlines Flight 811 reports on the split forward cargo door discuss the latching pins but omits the status of the midspan latch cams while the aft cargo door is intact and latched. The midspan latch area had a rupture at the aft midspan latch of the forward cargo door, giving the characteristic outward petal shaped explosion of metal.

Trans World Airlines Flight 800 reports on only the bottom eight latches of the forward cargo door and omits any discussion of the midspan latches which are missing from the wreckage database while the aft cargo door status is unreported. Trans World Airlines Flight 800 photographs show clearly the large petal shaped ruptures at both the midspan latches of the forward cargo door.

Excerpts of official corroborative statements to support the match that all four flights had incomplete reports of the status of the forward cargo door while status of aft cargo door is usually reported.

Air India Flight 182

From the Canadian Aviation Occurrence Report 2.11.4.6 Section 42 All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. 2.4.3.6 From the video films of the wreckage it was found that the complete aft cargo door was intact and in its position except that it had come adrift slightly. The door was found latched at the bottom.

Pan Am Flight 103

From AAIB Aircraft Accident Report No 2/90 1.12.1.2 The Rosebank Crescent site Other items found in the wreckage included both body landing gears, the right wing landing gear, the left and right landing gear support beams and the cargo door (frames 1800-1920) which was latched. The CRAF door itself (latched) apart from the top area containing the hinge.

United Airlines Flight 811:

From NTSB AAR 92/02: 1.16.1.1 Before Recovery of the Door The forward mid-span latch pin was relatively undamaged. The aft mid-span latch pin had definite areas of damage. Both pins had wear areas where the cams would contact the pins during latching.

Trans World Airlines Flight 800:

From NTSB AAR 00/03: 1.16.4.4 Metallurgical Examination of the Forward Cargo Door The Safety Board also considered the possibility that the forward cargo door (the forward edge of which is located several feet aft of STA 520 on the lower right side of the fuselage) separated from the accident airplane in flight and that this separation initiated the breakup sequence. The Board examined the pieces of the forward cargo door, which were recovered from the yellow zone. All eight of the latching cams at the bottom of the door were recovered attached to pieces of the lower end of the door and were in the latched position. Additionally, the latching cams and pieces of the cargo door remained attached to the pins along the lower door sill. The hinge at the top of the door was broken into several pieces, but the hinge pin still held the various pieces of the hinge together. There was no evidence to suggest that this hinge separated. The forward cargo door exhibited severe crushing deformation and fragmentation, very similar to damage observed on the adjacent fuselage structure.

Public Docket Exhibit No. 15C, Report Number 97-82, Section 41/42 Joint, Forward Cargo Door, Examination of the lower lobe forward cargo door showed that all eight of the door latching cams remain attached (along with pieces of the door itself) to the pins along the lower door sill.

18. Air India Flight 182, Pan Am Flight 103, and Trans World Airlines Flight 800, and United Airlines Flight 811 to a much lesser extent, had similar debris patterns on the surface of the ground or sea bottom.

There was a denser, tight debris zone for the forward part of the aircraft and then scattered

in a trail for the rest of aircraft. The forward part of the aircraft debris was closest to the initial event site. United Airlines Flight 811 had limited wreckage and it was found by tracking radar information of the debris to the surface of the ocean. The similar debris patterns are to be expected because of the similar breakup amidships in flight.

Air India Flight 182 had the nose section and wing land in a localized zone with the rest of the aircraft spread out in a trail.

Pan Am Flight 103 had the forward fuselage fall in short trail and the aft fuselage in a loose trail with nose in one tightly packed zone.

United Airlines Flight 811 had pieces from the partial breakup of the forward fuselage fall to the sea.

Trans World Airlines Flight 800 had a tightly packed forward part of the fuselage fall in a zone and a looser trail for the aft fuselage.

Excerpts of official corroborative statements to support the match that all four flights had similar debris patterns.

Air India Flight 182

From the Canadian Aviation Occurrence Report 3.3 Aircraft Break-up Sequence The forward portion of the aircraft was highly localized, which indicates that it struck the water in one large mass. page 49. Although badly damaged, sections 41, 42, and 44, and the wing structure were located in a relatively localized area ... page 32. Section 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern... page 32. A third area which had some distinctive pattern was that of the engines, engine struts, and components and was localized ... page 32.

Pan Am Flight 103:

From AAIB Aircraft Accident Report No 2/90 1.12.1 General distribution of wreckage in the field The wreckage was distributed in two trails which became known as the northern and southern trails...page 15. The northern trail contained mainly wreckage from the rear fuselage, fin and the inner regions of both tailplanes together with structure and skin from the upper half of the fuselage forward to approximately the wing mid-chord position. page 17. The southern trail was easily defined...The trail contained numerous large items from the forward fuselage. page 18. 1.12.2.4 Baggage containers Discrimination between forward and rear cargo hold containers was relatively straightforward as the rear cargo hold wreckage was almost entirely confined to Lockerbie, whilst that from the forward hold was scattered along the southern wreckage trail.

United Airlines Flight 811:

From NTSB AAR 92/02: 1.12 Wreckage and Impact Information Navy radar near Honolulu tracked debris that fell from the airplane when the cargo door was lost. Refinement of the radar data led to a probable "splashdown" point in the ocean.

Trans World Airlines Flight 800:

From NTSB AAR 00/03: 1.12 Wreckage Recovery and Documentation Information Pieces of the wreckage were distributed along a northeasterly 123 path

about 4 miles long by 3 1/2 miles wide in the Atlantic Ocean off the coast of Long Island.

1.12.1 Wreckage Recovered from the Red Zone The red zone was the largest of the three zones and was located farthest west (closest to JFK) in the wreckage distribution. Pieces recovered from the red zone generally included pieces from between about fuselage STA 840 and about fuselage STA 1000 (the aft portion of section 42 see figure 3a for station references); the structure from the aft end of the forward cargo compartment; and pieces from the WCS, including most of the front spar, a large portion of SWB3, and the manufacturing access door from SWB2.

1.12.2 Wreckage Recovered from the Yellow Zone The yellow zone was the smallest of the three zones and was contained within the red zone on its northeastern side (see figure 22a). This zone contained pieces of the airplane's forward fuselage, from about STA 840 to the nose of the airplane (STA 90). The wreckage recovered from the yellow zone included nearly all of fuselage section 41 (the nose section) and the forward portions of fuselage section 42.

1.12.3 Wreckage Recovered from the Green Zone The green zone was located farthest east (farthest from JFK) in the wreckage distribution. Most of the airplane wreckage was recovered from this zone, including most of the pieces of both wings, all four engines, and the fuselage aft of about STA 1000 (fuselage sections 44, 46, and 48 see figures 3a and 3b for reference).

19. Summary of matching evidence for all aircraft:

There is overwhelming circumstantial and tangible evidence from the five aircraft accident reports that all four aircraft suffered a breakup in flight amidships caused by an explosion in the forward cargo compartment. One aircraft had a partial breakup, United Airlines Flight 811, and was fortunately able to land with its invaluable evidence for a positive incontrovertible explanation for the tremendous explosion of explosive decompression which created the tangible evidence of CVR, FDR, inflight damage, engine damage, and injuries to passengers which matches the other other three accidents in many significant ways as detailed below in Table 1:

Significant Direct and Tangible Evidence Obtained for Four B747 Breakups in Flight

	AI 182	PA103	UAL 811	TWA 800
Boeing 747	Yes	Yes	Yes	Yes
Early model -100 or -200	Yes	Yes	Yes	Yes
Polyimide wiring (Poly X type)	Yes	Yes	Yes	Yes
Sudden airframe breakup in flight (partial or total)	Yes	Yes	Yes	Yes
Breakup occurs amidships	Yes	Yes	Yes	Yes
High flight time (over 55,000 flight hours)	No	Yes	Yes	Yes
Aged airframe (over 18 years of service)	No	Yes	Yes	Yes
Previous maintenance problems with forward cargo door	Yes	Maybe	Yes	Maybe
Initial event within an hour after takeoff	No	Yes	Yes	Yes
Initial event at about 300 knots while proceeding normally in all parameters	Yes	Yes	Yes	Yes
Initial event has unusual radar contacts	Maybe	Yes	Yes	Yes
Initial event involves hull rupture in or near forward cargo door area	Yes	Yes	Yes	Yes
Initial event starts with sudden sound	Yes	Yes	Yes	Yes
Initial event sound is loud	Yes	Yes	Yes	Yes
Initial event sound is audible to humans	Yes	Yes	Yes	Yes
Initial event followed immediately by abrupt power cut to data recorders	Yes	Yes	Yes	Yes
Initial event sound matched to explosion of bomb sound	No	No	No	No

Initial event sound matched to explosive decompression sound in wide body airliner	Yes	Yes	Yes	Yes
Torn off skin on fuselage above forward cargo door area	Yes	Yes	Yes	Yes
Unusual paint smears on and above forward cargo door	Maybe	Maybe	Yes	Yes
Evidence of explosion in forward cargo compartment	Yes	Yes	Yes	Yes
Foreign object damage to engine or cowling of engine number three	Yes	Yes	Yes	Yes
Fire/soot in engine number three	Maybe	Yes	Yes	Yes
Foreign object damage to engine or cowling of engine number four	Yes	Yes	Yes	Yes
Right wing leading edge damaged in flight	Yes	Maybe	Yes	Maybe
Vertical stabilizer damaged in flight	Yes	Yes	Yes	Maybe
Right horizontal stabilizer damaged in flight	Yes	Yes	Yes	Yes
More severe inflight damage on starboard side than port side	Yes	Yes	Yes	Yes
Port side relatively undamaged by inflight debris	Yes	Yes	Yes	Yes
Vertical fuselage tear lines just aft or forward of the forward cargo door	Yes	Yes	Yes	Yes
Fracture/tear/rupture at a midspan latch of forward cargo door	Maybe	Yes	Yes	Yes
Midspan latching status of forward cargo door reported as latched	No	No	No	No
Airworthiness Directive 88-12-04 implemented (stronger lock sectors)	No	No	No	Yes
Outwardly peeled skin on upper forward fuselage	Yes	Yes	Yes	Yes
Rectangular shape of shattered area around forward cargo door	Yes	Yes	Yes	Yes
Forward cargo door fractured in two longitudinally	Yes	Yes	Yes	Maybe
Status of aft cargo door as intact and latched	Yes	Yes	Yes	Maybe
Passengers suffered decompression type injuries	Yes	Yes	Yes	Yes
At least nine missing and never recovered passenger bodies	Yes	Yes	Yes	Yes
Wreckage debris field in two main areas, forward and aft sections of aircraft	Yes	Yes	No	Yes
Initial official opinion of probable cause as bomb explosion.	Yes	Yes	Yes	Yes
Initial official opinion modified from bomb explosion	Yes	Yes	Yes	Yes
Structural failure considered for probable cause	Yes	Yes	Yes	Yes
Inadvertently opened forward cargo door considered for probable cause	Yes	No	Yes	Yes
Official probable cause as bomb explosion	Yes	Yes	No	No
Official probable cause as 'improvised explosive device'	No	Yes	No	No
Official probable cause as explosion by unstated cause	Yes	No	No	No
Official probable cause as explosion in center fuel tank with unknown ignition source	No	No	No	Yes
Official probable cause as improper latching of forward cargo door	No	No	Yes	No
Official probable cause as switch /wiring inadvertently opening forward cargo door	No	No	Yes	No
"Bomb' allegedly loaded two flights previous to detonation flight	Yes	Yes	N/A	N/A
"Bomb' allegedly loaded one flight previous to detonation flight	N/A	N/A	N/A	Yes
Takeoff after sunset on fatal flight	Yes	Yes	Yes	Yes
Takeoff after scheduled takeoff time on fatal flight	Yes	Yes	Yes	Yes
"Bomb' allegedly goes off on ground after a flight	N/A	N/A	N/A	N/A
Significant Direct and Tangible Evidence Obtained for Four B747 Breakups in Flight				

AI 182 PA103 UAL 811 TWA 800

20. Summary of matching evidence between Pan Am Flight 103 and United Airlines Flight 811 specifically:

Aged.

High flight time.

Early model-100.

Poly x wired.

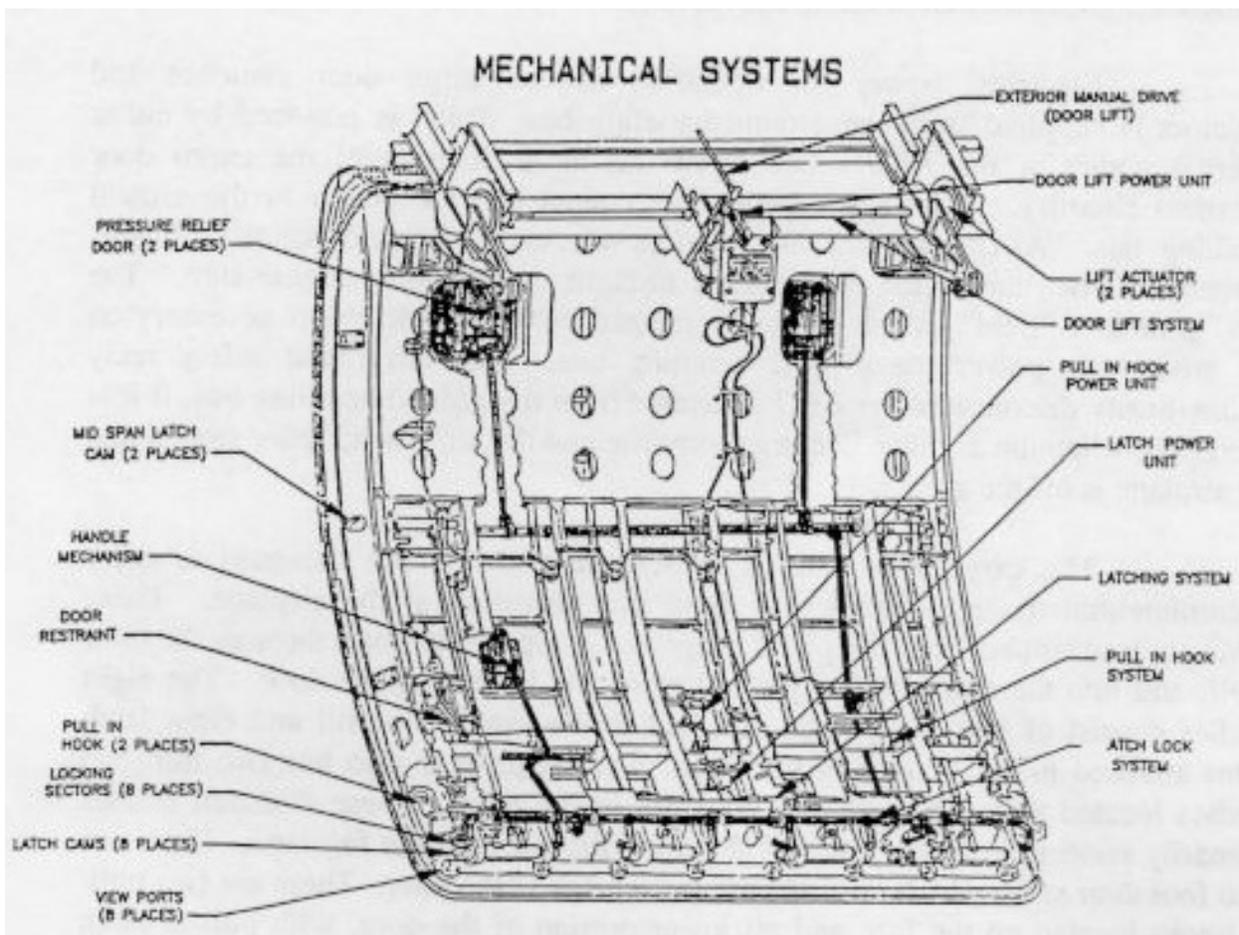
Boeing 747.

Experienced hull rupture forward of the wing on right side in cargo door area.

Shape of hull rupture forward of the wing on the right side is rectangle with specific rectangular shape.

Fodded number three engine.
 On fire number three engine.
 Sudden sound on CVR
 Loud sound on the CVR.
 Short duration sound on the CVR.
 Abrupt power cut to FDR.
 Outwardly peeled and down skin in cargo door area from aft midspan latch.
 Longitudinal break at midline of the forward cargo door at midspan latch.
 More severe inflight damage on starboard side.
 At least nine never recovered bodies.
 Vertical fuselage tear lines forward of the wing and aft of cargo door.
 Torn off and missing skin in forward cargo door area on starboard side.
 Outward peeled skin on upper forward fuselage.
 Destruction initially thought to be have been caused by a bomb.

21. Cargo Door Operation for Boeing 747: Drawing below of Boeing 747 cargo door from NTSB AAR 92/02



From AAR 92/02 United Airlines Flight 811: 1.6.2 Cargo Door Description and Operation: Normally, the cargo doors are operated electrically by means of a switch located on the exterior of the fuselage, just forward of the door opening. The

switch controls the opening and closing and the latching of the door. If at any time the switch is released, the switch will return to a neutral position, power is removed from all actuators, and movement of the actuators ceases.

In order to close the cargo door, the door switch is held to the "closed" position, energizing the closing actuator, and the door moves toward the closed position. After the door has reached the near closed position, the hook position switch transfers the electrical control power to the pull-in hook actuator, and the cargo door is brought to the closed position by the pull-in hooks. When the pull-in hooks reach their fully closed position, the hook-closed switch transfers electrical power to the latch actuator. The latch actuator rotates the eight latch cams, mounted on the lower portion of the door, around the eight latch pins, attached to the lower door sill. At the same time, the two midspan latch cams, located on the sides of the door rotate around the two midspan latch pins located on the sides of the door frame. When the eight latch cams and the two mid-span cams reach their fully closed position, electrical power is removed from the latch actuator by the latch-closed switch. This completes the electrically powered portion of the door closing operation. The door can also be operated in the same manner electrically by a switch located inside the cargo compartment adjacent to the door.

The final securing operation is the movement of lock sectors across the latch cams. These are manually moved in place across the open mouth of each of the eight lower cams through mechanical linkages to the master latch lock handle. The position of the lock sectors is indicated indirectly by noting visually the closed position of the two pressure relief doors located on the upper section of each cargo door. The pressure relief doors are designed to relieve any residual pressure differential before the cargo doors are opened after landing, and to prevent pressurization of the airplane should the airplane depart with the cargo doors not properly secured. The pressure relief doors are mechanically linked to the movement of the lock sectors. This final procedure also actuates the master latch lock switch, removing electrical control power from the opening and closing control circuits, and also extinguishes the cockpit cargo door warning light through a switch located on one of the pressure relief doors. Opening the cargo door is accomplished by reversing the above procedure.

The cargo door and its associated hardware are designed to carry circumferential (hoop) loads arising from pressurization of the airplane. These loads are transmitted from the piano hinge at the top of the door, through the door itself, and into the eight latches located along the bottom of the door. The eight latches consist of eight latch pins attached to the lower door sill and eight latch cams attached to the bottom of the door. The cargo door also has two midspan latches located along the fore and aft sides of the door. These midspan latches primarily serve to keep the sides of the door aligned with the fuselage. There are also four door stops which limit inward movement of the door. There are two pull-in hooks located on the fore and aft lower portion of the door, with pull-in hook pins on the sides of the door frame.' (Appendix F, Cargo Door Incidents)

22. Inadvertent Cargo Door Opening Causes:

Once the direct and tangible evidence established that all four aircraft suffered a breakup in flight caused by an explosive decompression in the forward cargo compartment at the forward

cargo door, the question became, "What made the forward cargo door suddenly rupture open in flight?"

There are many ways for an explosion to occur in the forward cargo compartment at the forward cargo door: (Current official opinion in parentheses)

- A. Bomb explosion. (Partially accepted for two flights, ruled out for two flights.)
- B. Crew or passenger error. (Ruled out for all flights.)
- C. Electrical fault in switch or wiring. (Accepted for two flights, ruled out for two flights.)
- D. Pneumatic overpressure. (Ruled out for all flights.)
- E. Cargo shift. (Ruled out for all flights.)
- F. Compressed air tank explosion. (Ruled out for all flights.)
- G. Fire in compartment. (Ruled out for all flights.)
- H. Missile strike. (Ruled out for all flights.)
- I. Midair collision. (Ruled out for all flights.)
- J. Fuel tank explosion. (Accepted for one flight, ruled out for three flights.)
- K. Stowaway. (Ruled out for all flights.)
- L. Electromagnetic interference. (Ruled out for all flights.)
- M. Comet or meteor. (Ruled out for all flights.)
- N. Space debris. (Ruled out for all flights.)
- O. Turbulence. (Ruled out for all flights.)
- P. Out of rig door. (Ruled out for all flights.)
- Q. Lightning. (Ruled out for all flights.)
- R. Metal fatigue. (Ruled out for all flights.)
- S. Improperly latched. (Initially accepted for one flight, then ruled out for all flights.)
- T. Design error. (Accepted for one flight, ruled out for three flights.)
- U. Repair error. (Ruled out for all flights.)
- V. Maintenance error. (Accepted for one flight, ruled out for three flights.)
- W. Collision with terrain. (Ruled out for all flights.)

The four aircraft have had most of these probable causes considered at one time or the other by the authorities in varying degrees of attention. The initial answers were wrong twice for United Airlines Flight 811 and Trans World Airlines Flight 800 and modified for Air India Flight 182 and Pan Am 103. United Airlines Flight 811 was at first explained as a bomb explosion, then it was changed to an improperly latched forward cargo door, then finally it was determined to be an electrical switch or wiring to cause the forward cargo door to open in flight. Trans World Airlines Flight 800 was at first explained as a bomb explosion, then a missile strike, and currently a center fuel tank explosion by an undetermined ignition source.

The current official probable causes for all four are ambiguous or mysterious:

- A. Air India Flight 182 Explosion of unstated cause or explosion of a bomb.
- B. Pan Am Flight 103: Improvised explosive device or a bomb.
- C. United Airlines Flight 811: Electrical switch or wiring causing forward cargo door to open in flight.
- D. Trans World Airlines Flight 800: Center fuel tank explosion by unknown ignition source with wiring the main suspect.

In all the cases, based upon the evidence now available to this investigator, an explosion occurred in the forward cargo compartment on the starboard side at event start time; in all cases explosive decompression in the forward cargo compartment caused a tremendous explosion which mimics a bomb or fuel tank explosion; and in all cases there is much matching direct, tangible and circumstantial evidence to the one accident which has the irrefutable probable cause, United

Airlines Flight 811, with the electrical switch or wiring causing the forward cargo door to rupture open inflight causing an explosion of explosive decompression in the forward cargo compartment.

Time has allowed this investigator to add further refinements to the confirmed probable cause of United Airlines Flight 811 in two ways; the location in the forward cargo door that ruptures first has been identified as one or both of the midspan latches and that the wiring has now been shown to be faulty in that it cracks and chafes to bare wire easily, especially in the presence of moisture.

The midspan latch area of the forward cargo door of United Airlines Flight 811, the reference accident, had a rupture at the aft midspan latch, showing the characteristic outward petal shaped explosion of metal. Air India Flight 182 describes the entire door in shattered terms of outward curled metal which would include the midspan latches and describes a longitudinal split near the latches. Pan Am Flight 103 shows a reconstruction drawing of a longitudinal split at the midspan latches and a photograph showing the characteristic peeled out and down skin from the aft midspan latch. Trans World Airlines Flight 800 shows clearly the large petal shaped ruptures at both the midspan latches of the forward cargo door.

The midspan latches have no locking sectors to prevent the inadvertent backdriving of the latching cams while the bottom eight latching cams do have the eight safety locking sectors. Each midspan latch holds together an eight foot slice of fuselage skin at the aft and forward edges of the cargo door against the tens of thousands of pounds of internal pressure exerted outward in flight.

The matching evidence of missing midspan latches, the large slice of fuselage the latches hold together, the lack of locking sectors on those midspan latches, the lack of a status report on the latches, and drawings and photographs of ruptures at those latch locations on the actual doors on all four aircraft indicates the ruptures in the forward cargo door on all four aircraft occurred at one or both of the midspan latches as the initial event leading to the explosive decompression and airframe breakup.

The investigation authorities in 1985/1986/1989/1990/1992/1996 also did not know of the faulty Poly X wiring because the faults of that type insulated wire only became apparent years later. That defective type of wiring, which was on Air India Flight 182, was implicated in the explosive decompression of United Airlines Flight 811. Also, the investigators of 1985 did not have the sound of the explosive decompression in the forward cargo compartment of a early model Boeing 747 which occurred in 1989 to match with Air India Flight 182 in 1985. They would have discovered the sounds of the Boeing 747 that was United Airlines Flight 811 matched the sudden loud sound of Air India Flight 182, just as the DC-10 explosive decompression sound matched Air India Flight 182.

If the 1985 CASB and AAIB and Indian investigators for Air India Flight 182 had had the UAL 811 NTSB AAR 92/02 and wiring records to review, they would have quickly discovered the many significant similarities and would probably have made the match between the two flights, and thus been able to make the right choice among an explosion of unstated cause, or a bomb explosion, or structural failure, or inadvertent rupture of the forward cargo door at one or both of the midspan latches due to faulty wiring causing the door to open in flight leading to explosive decompression.

23. Wiring:

The discovery of the faulty Poly X wiring, which was installed in all four aircraft, further narrows down the probable cause of the inadvertent door rupture to defective wiring. Cargo holds of Boeing 747s are known to have condensed water in them which accumulates in the bilges. The wire is of an aromatic polyimide type of insulation called Poly X. All four aircraft had this type of faulty wiring.

Excerpts of official corroborative statements to support the claim that Poly X wiring is defective: (Appendix G, Wiring)

Quote from Trans World Airlines Flight 800 Public Docket 516A, Exhibit 9A Systems Group Chairman's Factual report of Investigation, Page 47, "A Boeing telefax of June 25, 1997, stated that: The Poly-X wire was used as general purpose wire on the RA164 (TWA 800) aircraft. Wire insulation known as Poly-X had three in-service problems:

- Abrasion of the insulation in bundles installed in high vibration areas.

(This problem was corrected by Boeing Service Bulletin No. 747-71-7105, Dated July 19, 1974)

- Random flaking of the topcoat.

- Insulation radial cracks in tight bend radii.

Radial cracking phenomenon of the Poly-X wire was mainly associated with mechanical stress. Bend radius is the largest contributor to mechanical stress in installed wire or cable. Presence of moisture in conjunction with mechanical stress is also a contributor."

Trans World Airlines Flight 800 Public Docket 516A, Page 57, Letter from Commander Naval Air Systems Command to National Electrical Manufacturers Association, 1 Oct 82, "As you know, the problems with poly-x wire are well known to headquarters and its use had been curtailed."

From NTSB AAR 00/03 Trans World Airlines Flight 800: The results of these reviews are discussed in this section. Wiring-Related Accidents/Incidents In an October 21, 1996, fax, the Civil Aviation Authority of Singapore described an event that occurred on October 12, 1996, in which an operator reported that arcing in a wire bundle on a 747-200 cargo airplane had resulted in a fire at the aft bulkhead of the forward cargo compartment about STA 1000. The airplane was undergoing maintenance at the time of the fire, and subsequent inspection revealed damage to wire bundles W834, W846, W1524, and W370; the insulation blanket; the aft bulkhead of the forward cargo compartment; and (possibly) the CWT sealant. The operator removed the affected components from the airplane and shipped them to Boeing for examination and evaluation. A December 16, 1996, letter from Boeing stated that X-ray microanalysis and chemical identification of the damaged wire suggest that the insulation of the wire was damaged and that arcing had occurred between the damaged wires or that arcing between the damaged wires and ground had occurred.

24. Comment:

Aging aircraft problems such as cracking wiring do not get better with age; they get worse. Design problems such as inadequately latched non plug doors which open outward in flight can not be fixed by putting more latches on them. Aircraft accidents will happen and most are caused by mechanical problems or pilot error. A very small percent are caused by sabotage in the air. (Appendix H, Accidents). Subsequent problems to 1985 discovered in and around the forward cargo door of Boeing 747s were expressed as Airworthiness Directives (AD) or service bulletins (SB).

- A. The locking sectors on the bottom eight latches of both cargo doors needed to be strengthened.
- B. The lower sill of the forward cargo door needed strengthening.
- C. Section 41 needed to be strengthened.
- D. Instructions needed to be made clearer to ground personnel to not backdrive the latches.
- E. Caution placards needed to be easily understandable.
- F. Wire bundles alongside the forward cargo door needed to be rerouted so they would not bind and chafe.

25. General Conclusions for Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800:

When all the evidence is objectively considered using the hindsight of seventeen years, it is apparent that Air India Flight 182, Pan Am Flight 103, and Trans World Airlines Flight 800 have the same and only confirmed and irrefutable probable cause for the explosion of the explosive decompression in the forward cargo compartment that led to the breakup in flight, that of United Airlines Flight 811.

It is apparent that all four aircraft are related by direct, tangible, and circumstantial evidence to have suffered an amidships breakup in flight which occurred after an explosion on the starboard side in the forward cargo compartment which caused an explosive decompression, the cause of which was a suddenly ruptured open forward cargo door in flight probably at one or both of the midspan latches and probably caused by faulty wiring which turned on the door unlatch motor. The implications of these conclusions raises many questions which are addressed in Appendix I, Questions.

Based on the direct, tangible and circumstantial evidence of the four accidents, and using the benefit of hindsight, the conclusion of this investigator and author of this report is that the probable cause of the forward cargo door rupturing open in flight for the four aircraft was faulty wiring shorting on the door unlatch motor causing the forward cargo door to inadvertently rupture open in flight at one or both of the midspan latch leading to explosive decompression in the forward cargo compartment.

- A. Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 experienced inflight breakups.
- B. The breakup was caused by an explosion in the forward cargo compartment on the starboard side.
- C. The explosion was a severe and sudden explosive decompression.
- D. The explosive decompression was caused by the suddenly ruptured open forward cargo door probably at one or both of the midspan latches.
- E. The ruptured open forward cargo door was probably caused by faulty wiring which

turned on the door unlatch motor which unlatched the latching cams from around the latching pins in flight.

F. The wiring fault was probably the Poly X wiring with inferior insulation which easily cracked to bare wire especially in the presence of moisture.

G. There were no bomb explosions in any cargo compartment, crew cabin, passenger cabin, or anywhere else in any of the aircraft.

26. Specific Conclusions for Pan Am Flight 103:

These conclusions are based on evidence available before and after 1988.

A. While proceeding normally, an inflight breakup of Pan Am Flight 103 occurred suddenly and catastrophically at 31000 feet at 300 knots TAS. There were no survivors.

B. The breakup was caused by an explosion in the forward cargo compartment.

C. The explosion was a severe and sudden explosive decompression.

D. The explosive decompression was caused by the suddenly ruptured open forward cargo door probably at one or both of the midspan latches.

E. The ruptured open forward cargo door was probably caused by faulty wiring which turned on the door unlatch motor which unlatched the latching cams from around the latching pins in flight.

F. The wiring fault was probably the Poly X wiring with inferior insulation which easily cracked to bare wire especially in the presence of moisture.

G. There was no bomb explosion in any cargo compartment, crew cabin, passenger cabin, or anywhere else on the aircraft.

H. There was no explosion in the aft cargo compartment.

I. The sudden loud sound on the cockpit voice recorder was the sound of the air rushing out during the explosive decompression in the forward cargo compartment.

J. The abrupt power cut to the recorders was caused by the explosive effects of the decompression affecting the power cables in the adjacent main equipment compartment to the forward cargo compartment.

27. Contributing causes:

A. Water or moisture in the forward cargo compartment.

B. Weak locking sectors on the bottom eight latches of the cargo doors.

C. Poor design of one midspan latch per each eight foot side of the cargo doors.

D. Poor design of no locking sector for each midspan latch of the cargo doors.

E. Poor design of outward opening nonplug type large, squarish cargo doors in a highly pressurized hull.

28. Recommendations:

A. An emergency airworthiness directive for immediate compliance should be issued for all operators of early model Boeing 747s to visually and electrically wire check all the wiring for integrity in the forward cargo door area as well as all wiring involved with operation of the forward cargo door.

B. All unnecessary electrical equipment on early model Boeing 747s should be turned off and remain off during flight.

C. All early model Boeing 747s should have the Poly X insulated wiring removed or isolated and replaced as soon as practicable.

D. All early model Boeing 747s should have the aft and forward outward opening nonplug cargo doors sealed shut permanently or modified into plug type doors.

E. The cargo door power circuit breaker may be pulled out at crew's discretion.

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**AIRCRAFT
ACCIDENT
REPORT
Pan Am Flight 103
Part III:
Door Story**



**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

Part III: Door Story

Forward Cargo Door Areas Compared for United Airlines Flight 811, Pan Am Flight 103, Air India Flight 182, and Trans World Airlines Flight 800.

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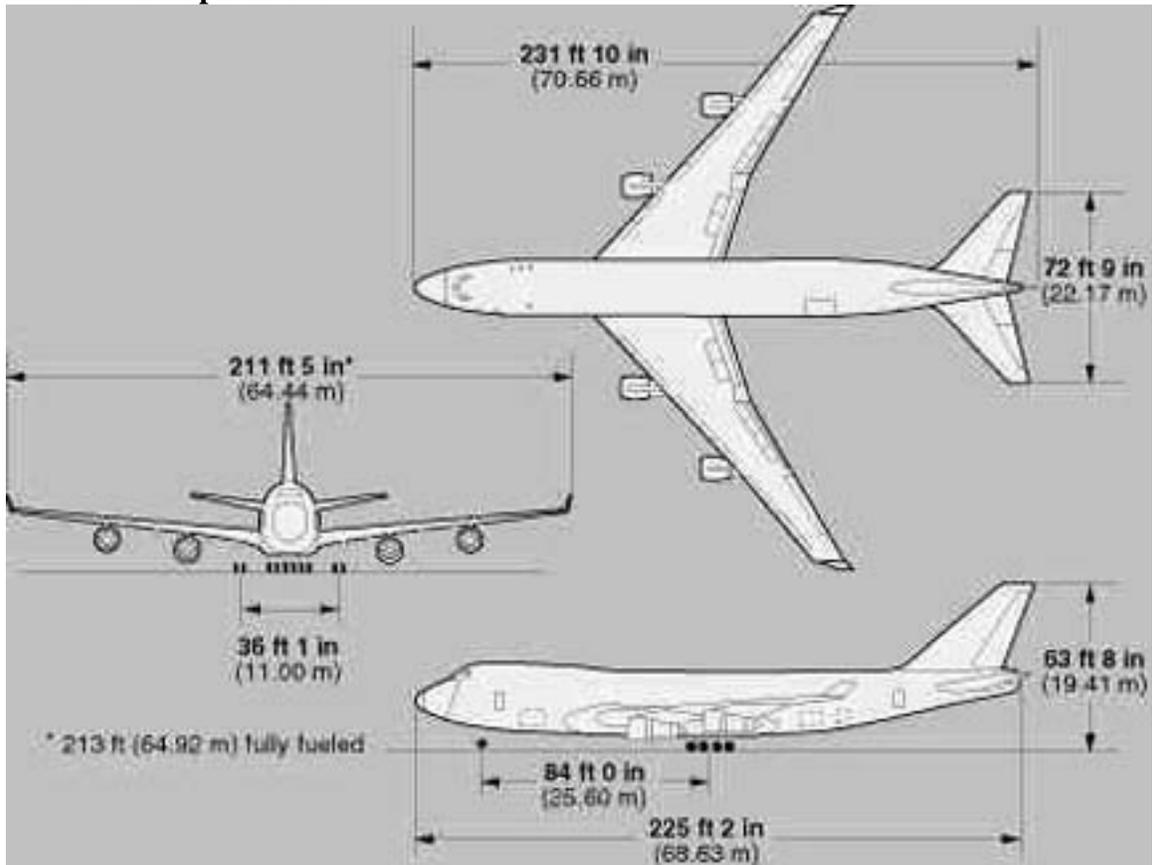
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2. Normal Operation.
3. United Airlines Flight 811.
4. Air India Flight 182.
5. Pan Am Flight 103.
6. Trans World Airlines Flight 800
7. Conclusions.

1. Introduction.

The forward cargo door areas of four fatal Boeing 747 accidents are examined and analyzed in schematics, photographs, and drawings from official government aircraft accident reports, press reports, and private files. The aircraft are Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800. The similarities of location of damage are revealed in the vertical tear lines above the cargo door, the outwardly peeled fuselage skin and door skin, the essential missing parts of the door such as latches and locking handle, petal shaped ruptures, and the general overall appearance of a shattered fuselage forward of the wing on the right side. The relatively smooth port sides are shown also when available. A conclusion may be made that one cause may have been the initial event for all four accidents.

In addition, the normal operation of the forward cargo door is shown in pictures and described in text.

2. Normal operation.



Layout of Boeing 747 dimensions.



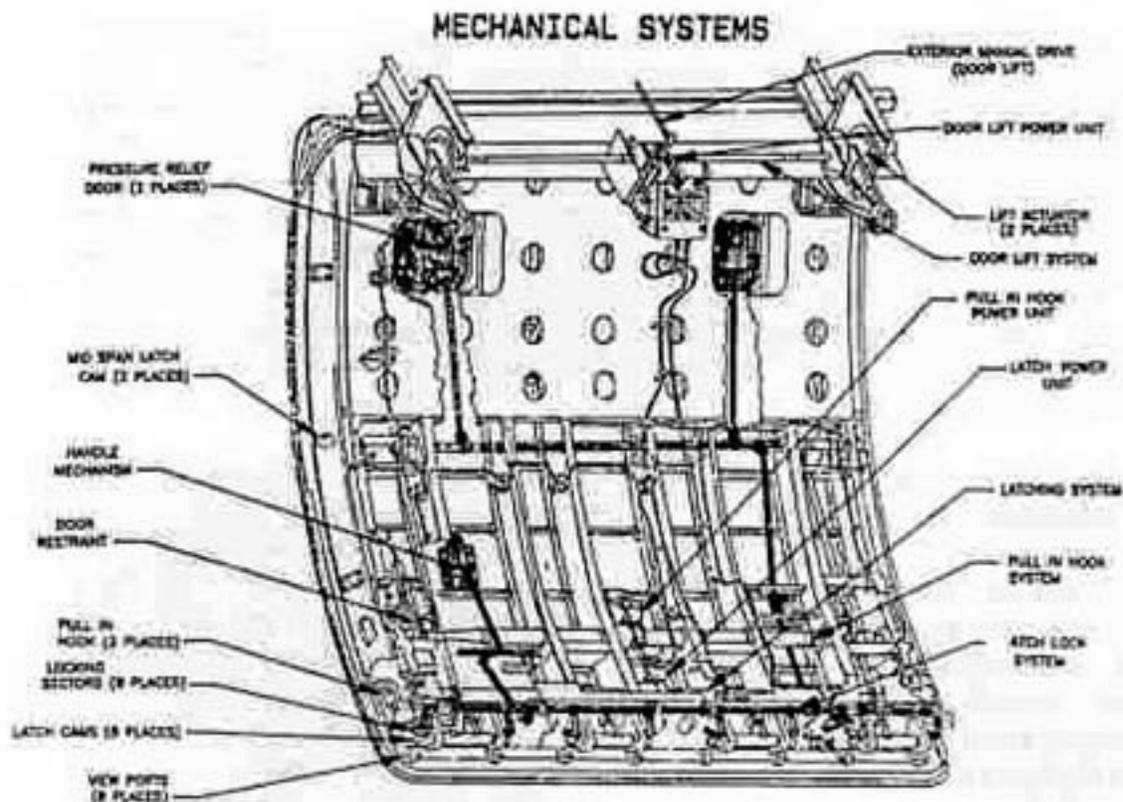
Boeing 747 on ground loading cargo through opening outward nonplug forward cargo door. The tiny dot of the one midspan latch on the leading edge of the door can be seen.



Closeup of Boeing 747 closed forward cargo door showing manual locking handle, upper hinge, over pressure relief doors, passenger windows above door, and R2 door.



Closeup of open forward cargo door showing open manual locking handle, several of the bottom eight latches, forward leading edge midspan latch, and the aft leading edge midspan latch pin.



Drawing of Boeing 747 cargo door from NTSB AAR 92/02.

1.6.2 Cargo Door Description and Operation

Both the forward and aft lower cargo doors are similar in appearance and operation. They are located on the lower right side of the fuselage and are outward-opening. The door opening is approximately 110 inches wide by 99 inches high, as measured along the fuselage.

Electrical power for operation of the cargo door switches and actuators is supplied from the ground handling bus, which is powered by either external power or the APU. See figure 17 for a diagram of the cargo door electrical circuitry. The engine generators cannot provide power to the ground handling bus. APU generator electrical power to the ground handling bus is interrupted when an engine generator is brought on line after engine start. The APU generator "field" switch can be reengaged by the flightcrew, if necessary on the ground, to power the ground handling bus. The air/ground safety relay automatically disconnects the APU generator from the ground handling bus, if it is energized, when the airplane becomes airborne and the air/ground relay senses that the airplane is off the ground.

The cargo door and its associated hardware are designed to carry circumferential (hoop) loads arising from pressurization of the airplane. These loads are transmitted from the piano hinge at the top of the door, through the door itself, and into the eight latches located along the bottom of the door. The eight latches consist of eight latch pins attached to the lower door sill and eight latch cams attached to the bottom of the door. The cargo door also has two midspan latches located along the fore and aft sides of the door. These midspan latches primarily serve to keep the sides of the door aligned with the fuselage. There are also four door stops which limit inward movement of the door. There are two pull-in hooks located on the fore and aft lower portion of the door, with

pull-in hook pins on the sides of the door frame.

The cargo doors on the B-747 have a master latch lock handle installed on the exterior of the door. The handle is opened and closed manually. The master latch lock handle simultaneously controls the operation of the latch lock sectors, which act as locks for the latch cams, and the two pressure relief doors located on the door. Figure 5 depicts a lock sector and latch cam in an unlocked and locked condition.

Figure 4.--Boeing 747 lower lobe forward cargo door.

Figure 5.--Cargo door latch cam and lock sector in unlocked and locked positions.

The door has three electrical actuators for opening/closing and latching of the door. One actuator (main actuator) moves the door from the fully open position to the near closed position, and vice versa. A second actuator (pull-in hook actuator) moves the pull-in hooks closed or open, and the third actuator (latch actuator) rotates the latch cams from the unlatched position to the latched position, and vice versa. The latch actuator has an internal clutch, which slips to limit the torque output of the actuator.

Normally, the cargo doors are operated electrically by means of a switch located on the exterior of the fuselage, just forward of the door opening. The switch controls the opening and closing and the latching of the door. If at any time the switch is released, the switch will return to a neutral position, power is removed from all actuators, and movement of the actuators ceases.

In order to close the cargo door, the door switch is held to the "closed" position, energizing the closing actuator, and the door moves toward the closed position. After the door has reached the near closed position, the hook position switch transfers the electrical control power to the pull-in hook actuator, and the cargo door is brought to the closed position by the pull-in hooks. When the pull-in hooks reach their fully closed position, the hook-closed switch transfers electrical power to the latch actuator. The latch actuator rotates the eight latch cams, mounted on the lower portion of the door, around the eight latch pins, attached to the lower door sill. At the same time, the two midspan latch cams, located on the sides of the door rotate around the two midspan latch pins located on the sides of the door frame. When the eight latch cams and the two mid-span cams reach their fully closed position, electrical power is removed from the latch actuator by the latch-closed switch. This completes the electrically powered portion of the door closing operation. The door can also be operated in the same manner electrically by a switch located inside the cargo compartment adjacent to the door.

The final securing operation is the movement of lock sectors across the latch cams. These are manually moved in place across the open mouth of each of the eight lower cams through mechanical linkages to the master latch lock handle. The position of the lock sectors is indicated indirectly by noting visually the closed position of the two pressure relief doors located on the upper section of each cargo door. The pressure relief doors are designed to relieve any residual pressure differential before the cargo doors are opened after landing, and to prevent pressurization of the airplane should the airplane depart with the cargo doors not properly secured. The pressure relief doors are mechanically linked to the movement of the lock sectors. This final procedure also actuates the master latch lock switch, removing electrical control power from the opening and closing control circuits, and also extinguishes the cockpit cargo door warning light through a switch located on one of the pressure relief doors. Opening the cargo door is accomplished by reversing the above procedure.

The B-747 cargo door has eight (8) view ports located beneath the latch cams for direct viewing of the position of the cams by means of alignment stripes. Procedures for using these view ports for verifying the position of the cams were not in place or required by Boeing, the FAA, or UAL (see 1.17.5 for additional information).

Closing the door manually is accomplished through the same sequence of actions without electrical power. The door actuator mechanisms are manually driven to a closed and latched position by the use of a one-half inch socket driver. The door can also be opened manually with the use of the socket driver. There are separate socket drives for the door raising/lowering mechanism, the pull-in

hooks, and the latches.

3. United Airlines Flight 811



United Airlines Boeing 747 in colors of 1989 with normally closed forward cargo door.

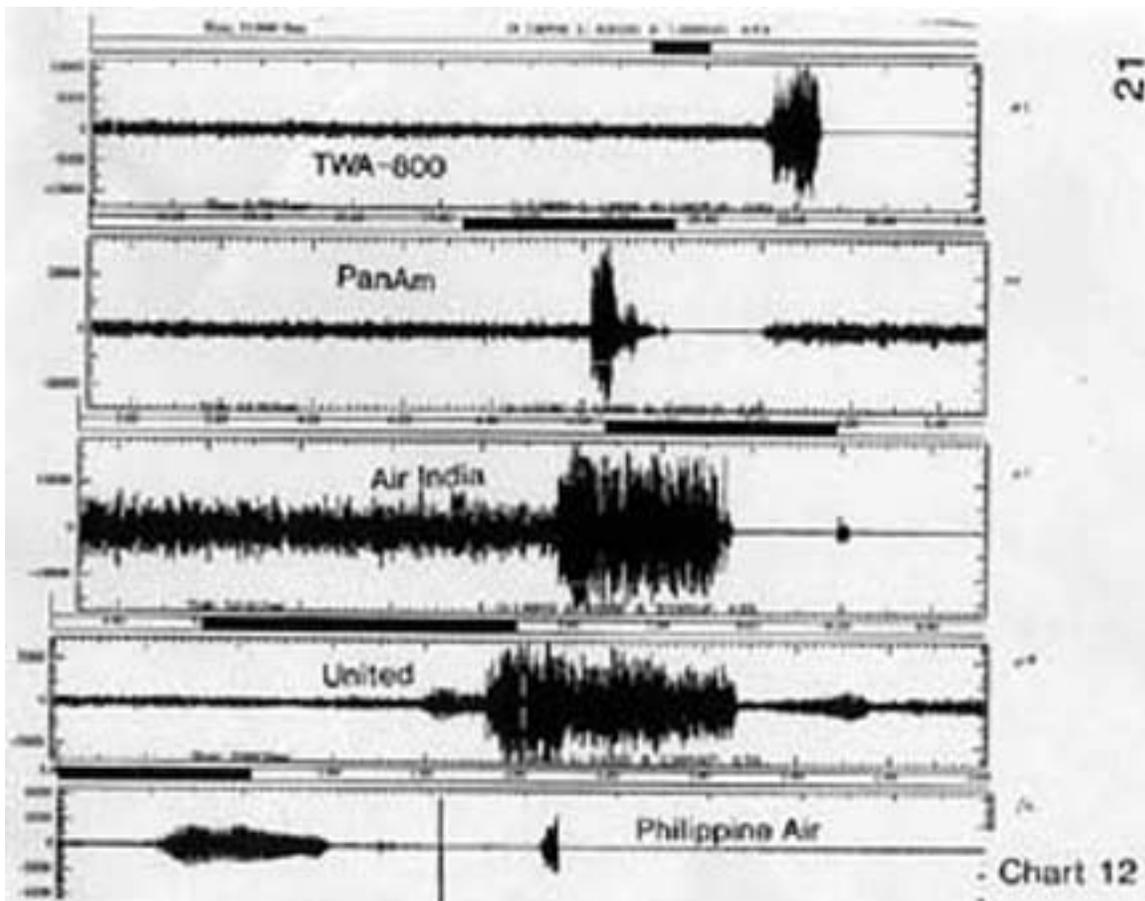


Chart 12 from Public Docket for Trans World Airlines Flight 800 comparing the sudden loud sounds from Trans World Airlines Flight 800, Pan Am Flight 103, Air India Flight 182, United Airlines Flight 811 and a Boeing 737.



Melodramatic artist's impression on cover of June 1989 Popular Mechanics showing United Airlines Flight 811 as it descends to land after inadvertent opening of forward cargo door in flight.



Photo of hole in United Airlines Flight 811 made by inadvertent opening of forward cargo door in flight.



Photo of hole in United Airlines Flight 811 made by inadvertent opening of forward cargo door in flight.



Photo from NTSB AAR 92/02 of hole in United Airlines Flight 811 made by inadvertent opening of forward cargo door in flight.

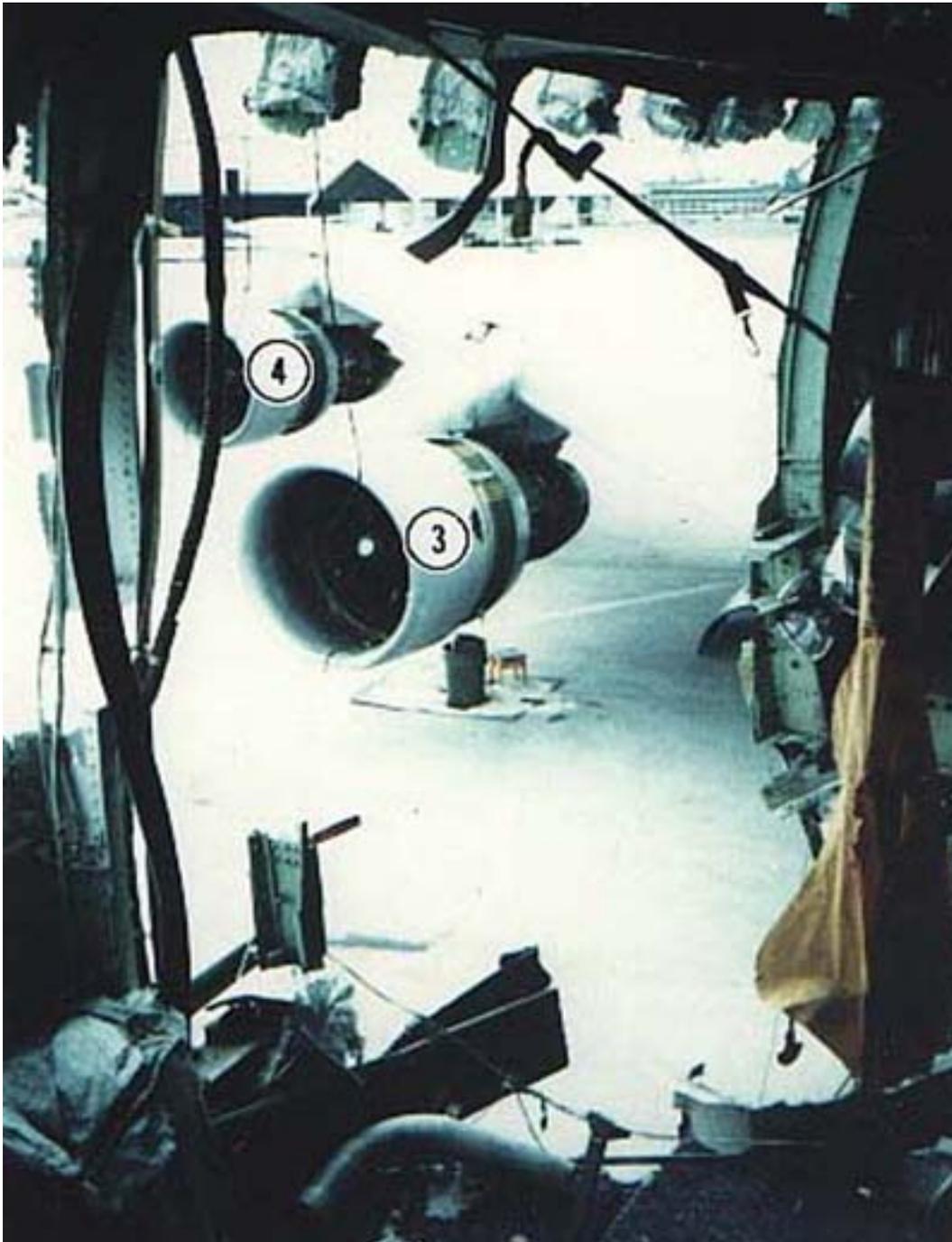
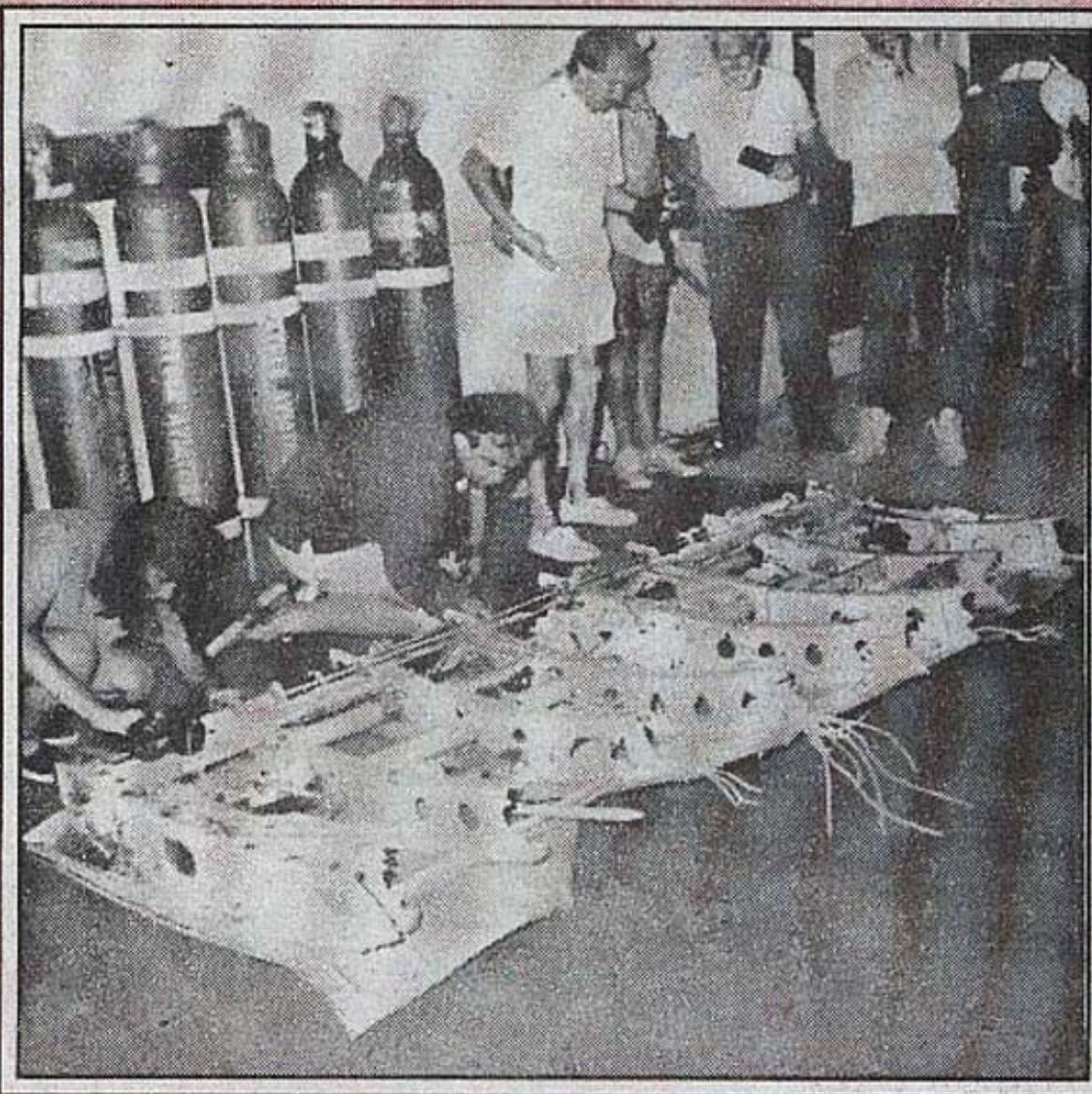


Photo from inside United Airlines Flight 811 showing the hole caused by inadvertent opening of forward cargo door in flight revealing engine numbers three and four which received the ejected foreign objects which caused the fire and internal engine damage.

Sea surrenders Flight 811 culprit



Navy photo by Omar Hasan

The bottom half of the cargo door from United Flight 811 is examined on board a Navy contract support ship after it was retrieved from a depth of nearly three miles. The crew of the mini-sub Sea Cliff hopes to recover the top half this weekend. See story on Page A3.

Photo of newspaper article and photograph showing the lower half of retrieved forward cargo door, loose wiring, the longitudinal split at midspan latches, and the peeled away skin from the aft midspan latch.



Photo from NTSB AAR 92/02 for United Airlines Flight 811 showing both halves of the retrieved door, the longitudinal split at midspan latches, and the peeled away skin from the aft midspan latch.



Photo from NTSB AAR 92/02 for United Airlines Flight 811 showing bottom half of the retrieved door, the longitudinal split at midspan latches, and the peeled away skin from the aft midspan latch.

United Airlines Flight 811:

"The CVR revealed normal communication before the decompression. At 0209:09:2 HST, a loud bang could be heard on the CVR. The loud bang was about 1.5 seconds after a "thump" was heard on the CVR for which one of the flightcrew made a comment. The electrical power to the CVR was lost for approximately 21.4 seconds following the loud bang. The CVR returned to normal operation at 0209:29 HST, and cockpit conversation continued to be recorded in a normal manner. NTSB Accident Report 92-02 Page 25

United Airlines Flight 811:

"However, the decompression event caused a data loss of approximately 2 1/2 seconds. When the data resumed being recorded, all values appeared valid with the exception of the pitch and roll parameters. Lateral acceleration showed a sharp increase immediately following the decompression. Vertical acceleration showed a sharp, rapid change just after the decompression and a slight increase as the airplane began its descent." NTSB AAR 92/02. page 25

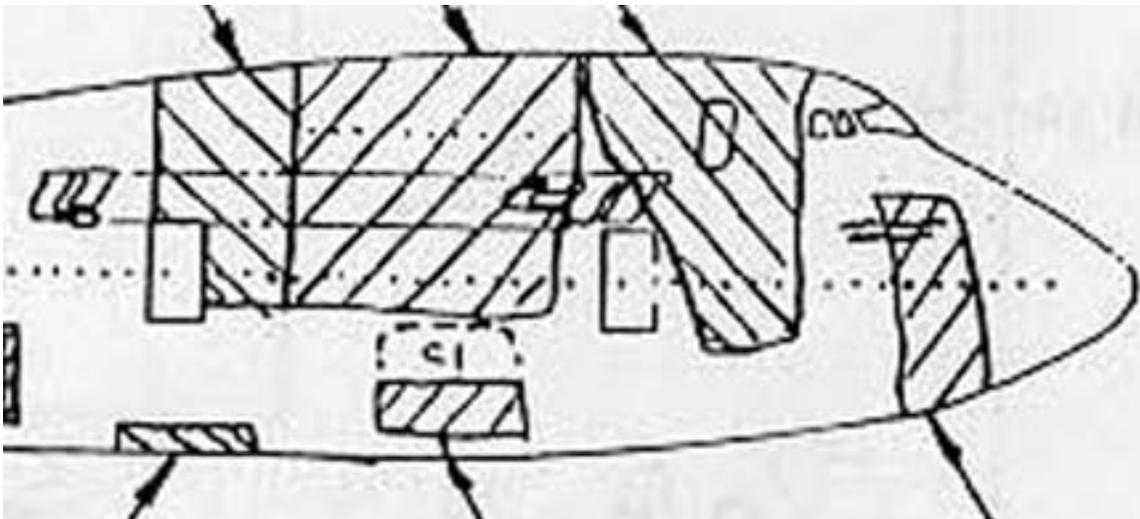
Regarding United Airlines Flight 811 from NTSB AAR 92/02 to explain the above evidence:

'The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked.'

4. Air India Flight 182



Photograph of Air India Boeing 747.



Reconstruction drawing from the Kirpal Report and the CASB report on Air India Flight 182 showing the longitudinal split of the forward cargo door and the vertical tearing of the skin above the door.

From the Kirpal report:

"2.11.4.6 All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed."

"After lunch with them I [Mr. Campbell] asked " in light of what we now know on 811 do you still think that Air India was a bomb ?"

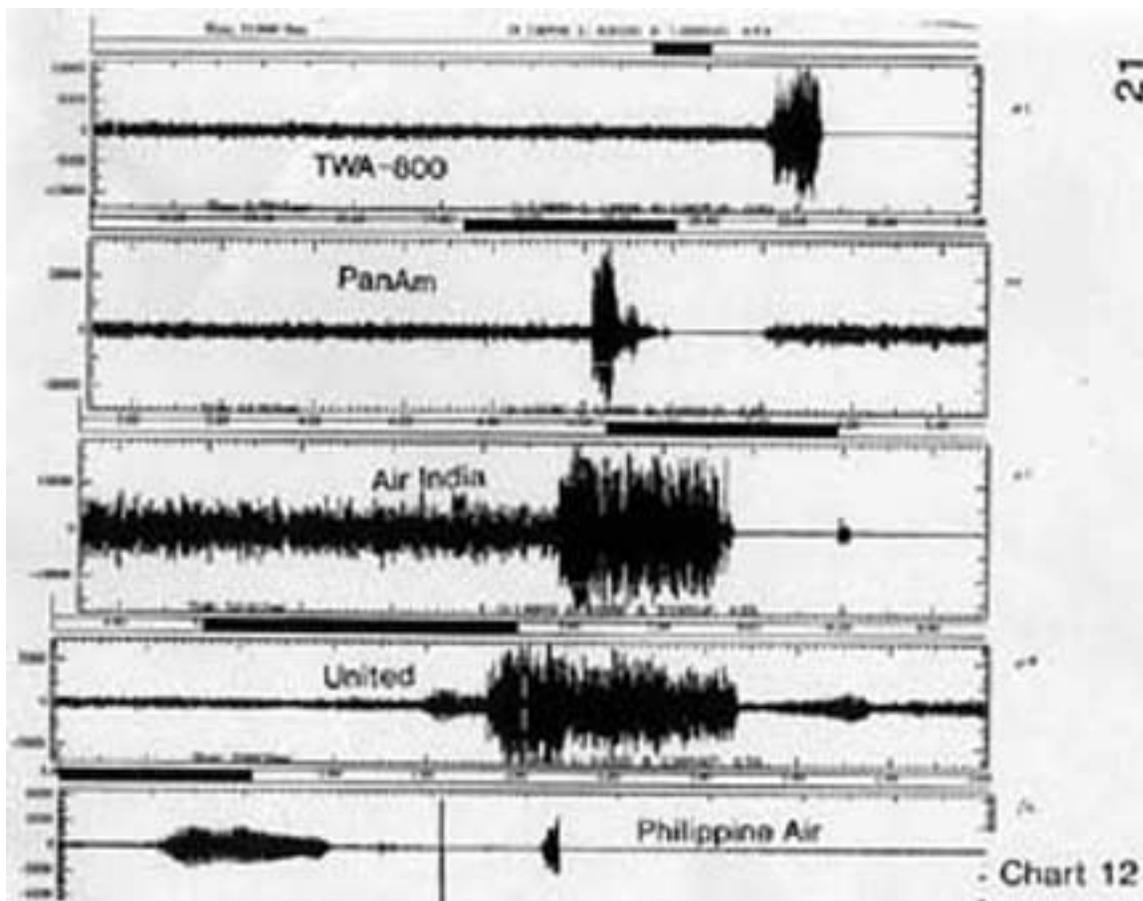
The reply was that we [NTSB] never thought that Air India was a bomb in fact the video shows a cargo door exactly the same as 811. I [Mr. Campbell] wrote to both Air India and the Canadian Safety Board with my findings on 811 but did not even have the courtesy of a reply ."

Quote above from correspondence of Mr. and Mrs Campbell discussing comments from NTSB officials matching United Airlines Flight 811 forward cargo door to Air India Flight 182 forward

cargo door.

B737, and a gun shot on the flight deck of a B737. Considering the different acoustic characteristics between a DC-10 and a B747, the AIB analysis indicates that there were distinct similarities between the sound of the explosive decompression on the DC-10 and the sound recorded on the AI 182 CVR.

Excerpt above from the Kirpal report and CASB report on Air India Flight 182 giving an explanation for the sudden loud sound which matches an explosive decompression open cargo door event on a DC-10, a widebody passenger airliner.



Air India Flight 182:

"From the CVR and DFDR, AI 182 was proceeding normally en route from Montreal to London at an altitude of 31,000 feet and an indicated airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound. The sound continued for about 0.6 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder." Canadian Aviation Safety Board Air India 23 June 1985, page 21

Canadian Aviation Safety Board Air India 23 June 1985, page 21 "When synchronized with other

recordings it was determined, within the accuracy that the procedure permitted, that the DFDR stopped recording simultaneously with the CVR." "Canadian Aviation Safety Board Air India 23 June 1985, page 22

4.0 CONCLUSIONS

The Canadian Aviation Safety Board respectfully submits as follows:

4.1 Cause-Related Findings

1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.
2. The forward and aft cargo compartments ruptured before water impact.
3. The section aft of the wings of the aircraft separated from the forward portion before water impact.
4. There is no evidence to indicate that structural failure of the aircraft was the lead event in this occurrence.
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the evidence does not support any other conclusion.

5. Pan Am Flight 103



Pan Am 747 showing colors of 1988 and open forward cargo door.



Staged bombing of a Boeing 747 at Bruntingthorpe UK showing the massive damage which occurs when a real bomb goes on in a Boeing 747.

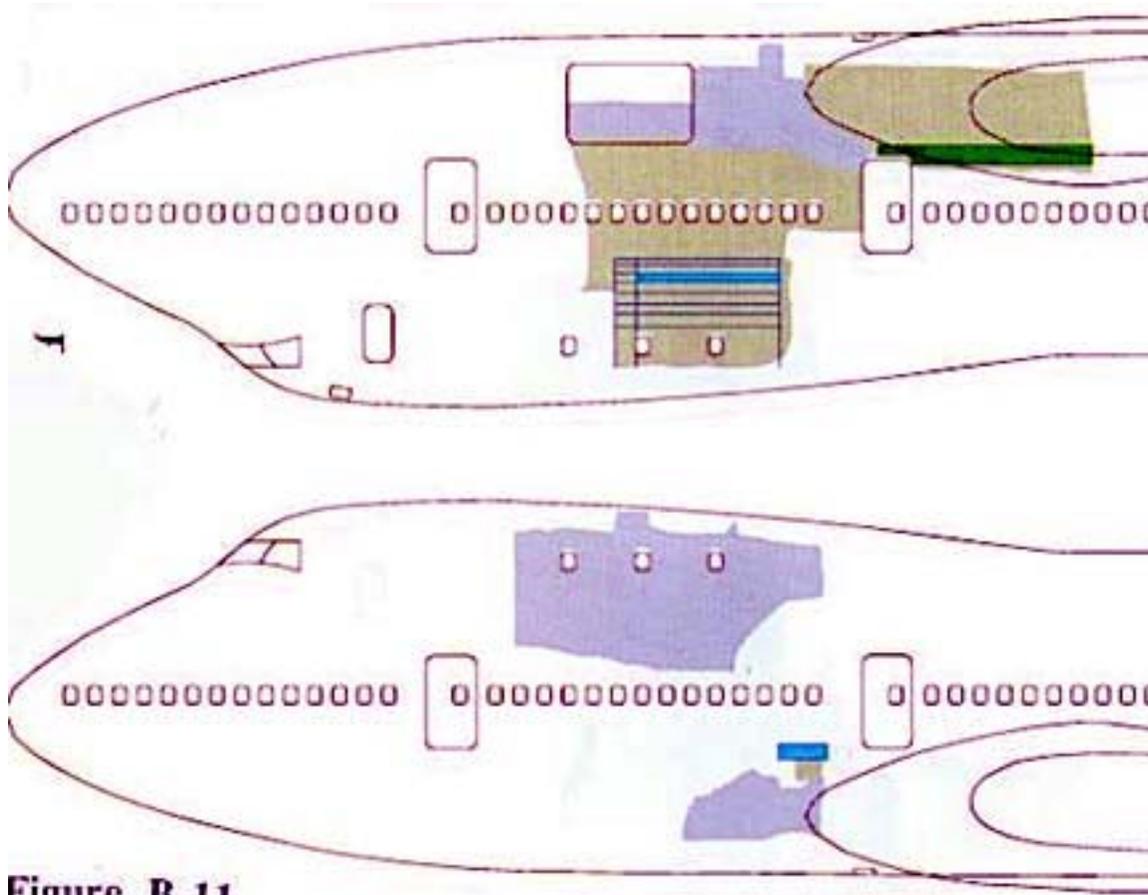
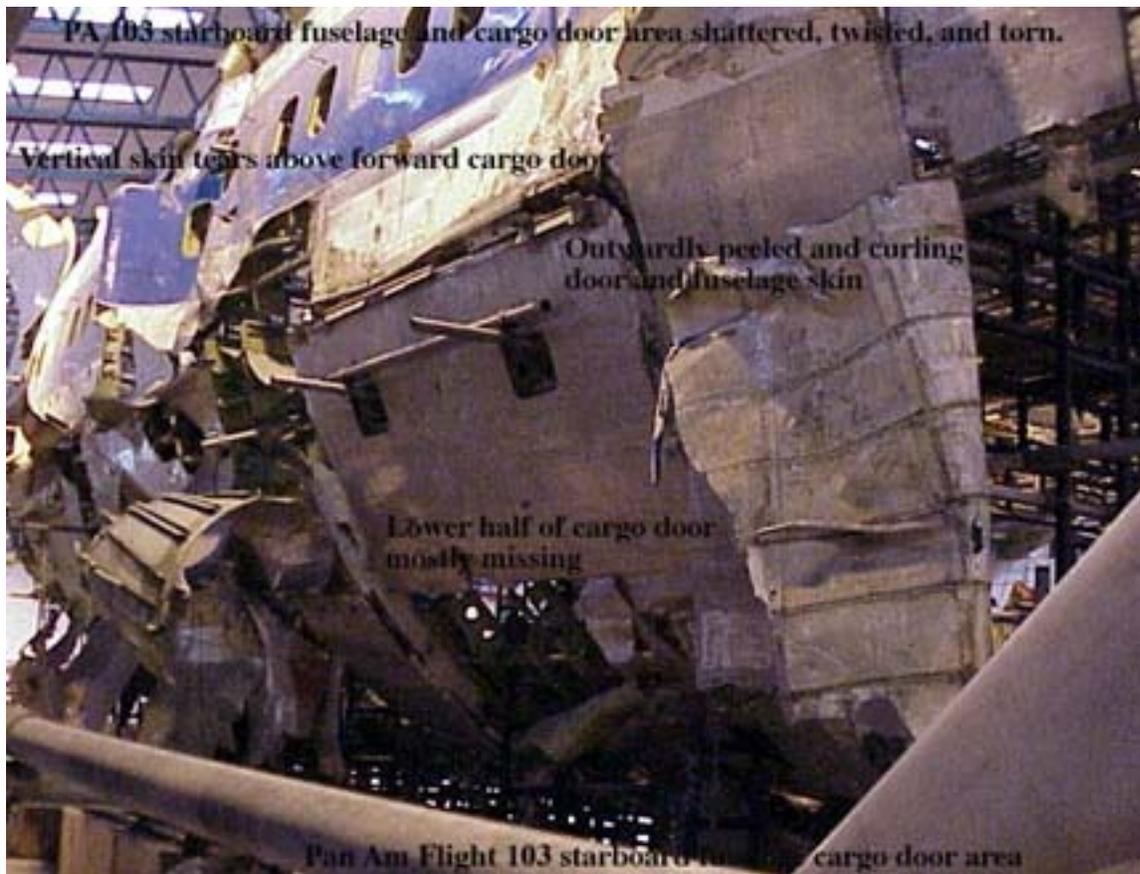


Figure B-11

Figure B11 from AAIB 2/90 for Pan Am Flight 103 showing initial event time fuselage destruction with small 'bomb' hole rectangle on port side and huge rectangular destruction around forward cargo door on starboard side.



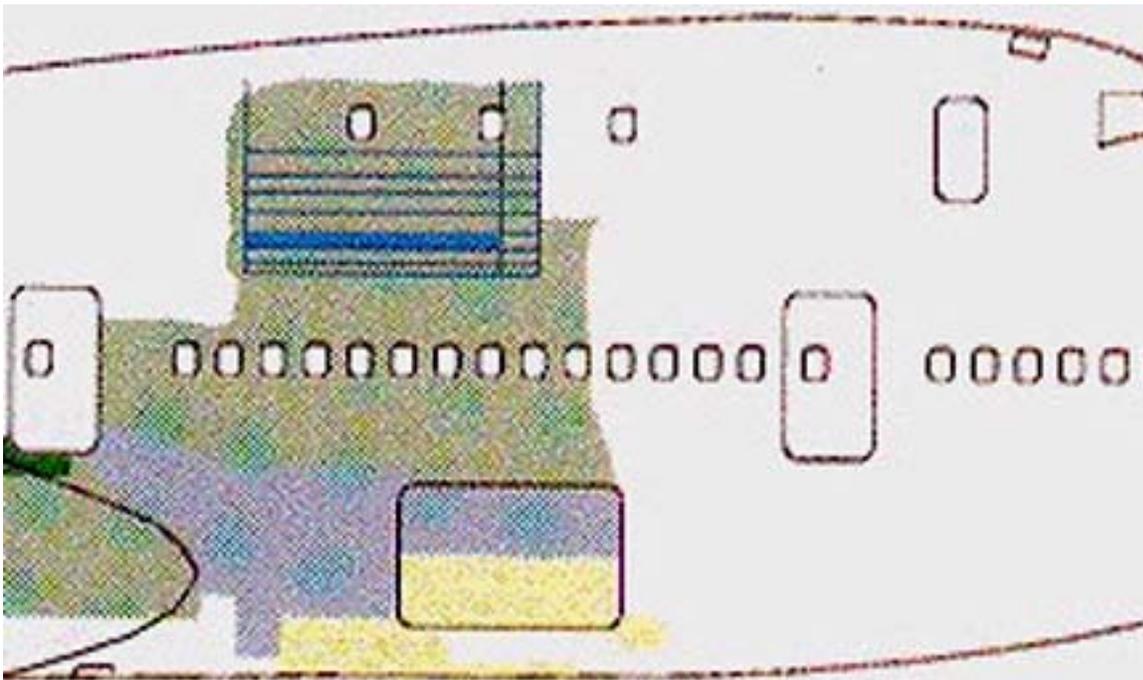
Port side of Pan Am Flight 103 forward of the wing showing the small 'bomb' hole and relatively smooth and intact fuselage skin around it.



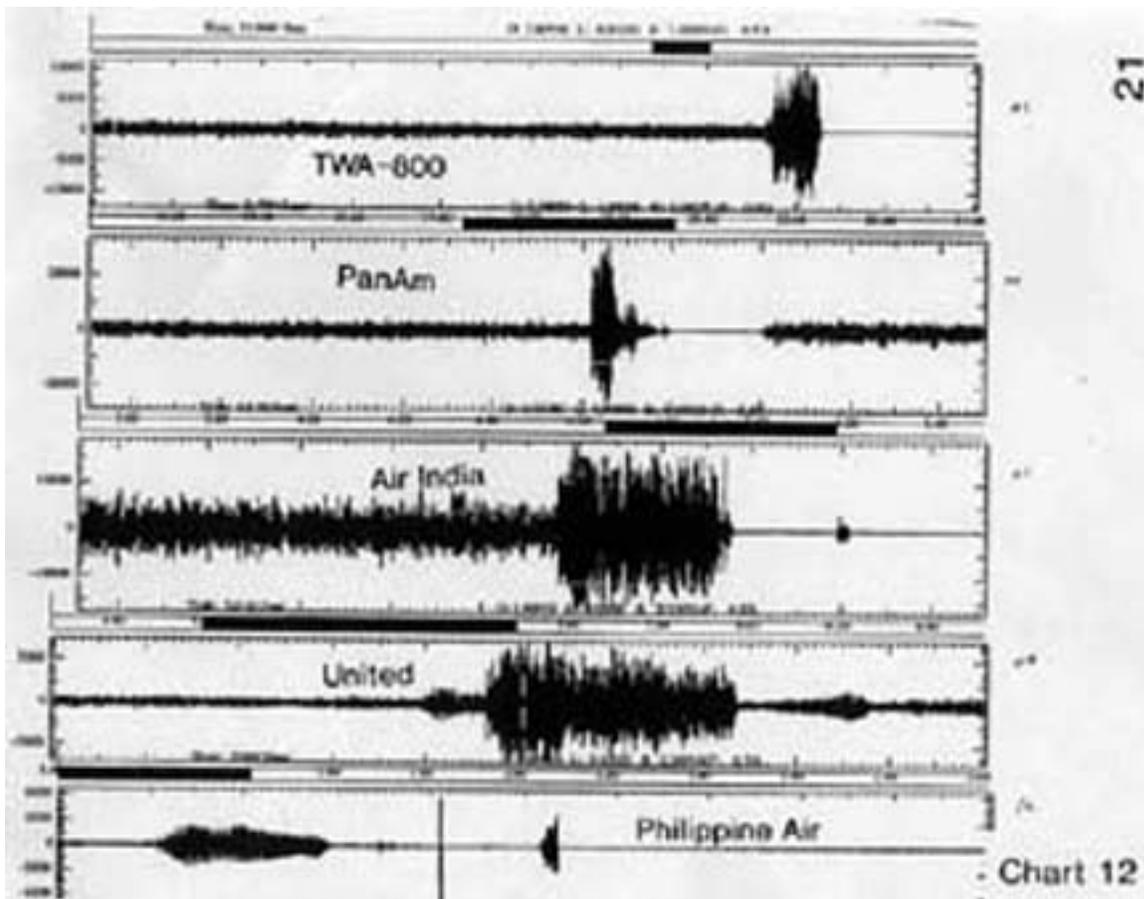
Photograph from AAIB showing Pan Am Flight 103 forward cargo door area revealing the vertical torn skin above door, peeled back and down skin from the aft midspan latch, generally shattered area, and mostly missing lower half of door which includes the manual locking handle and the eight bottom latches.



Closeup of the peeled back skin from the aft midspan latch of the forward cargo door of Pan Am Flight 103.



Reconstruction drawing from the AAIB 2/90 report on Pan Am Flight 103 showing the large area of torn off skin around the forward cargo door, the longitudinal split of the door, and the vertical tearing of the skin above the door.



Pan Am Flight 103:

"The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual crew behaviour. The tape record ended, at 19:02:50 hrs +- second, with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording whilst the crew were copying their transatlantic clearance from Shanwick ATC." UK AAIB Report 2/90 Page 15

Pan Am Flight 103:

"The analysis of the recording from the DFDR fitted to N739PA, which is detailed in Appendix C, showed that the recorded data simply stopped. Following careful examination and correlation of the various sources of recorded information, it was concluded that this occurred because the electrical power supply to the recorder had been interrupted at 19:02:50 +- second." UK AAIB Report 2/90 Page 37

'The report concludes that the detonation of an improvised explosive device led directly to the destruction of the aircraft with the loss of all 259 persons on board and 11 of the residents of the town of Lockerbie'

6. Trans World Airlines Flight 800



Photograph of Trans World Airlines Boeing 747 in 1996 colors.



Photograph of the port side of Trans World Airlines Flight 800 showing the relative undamaged skin forward of the wing.

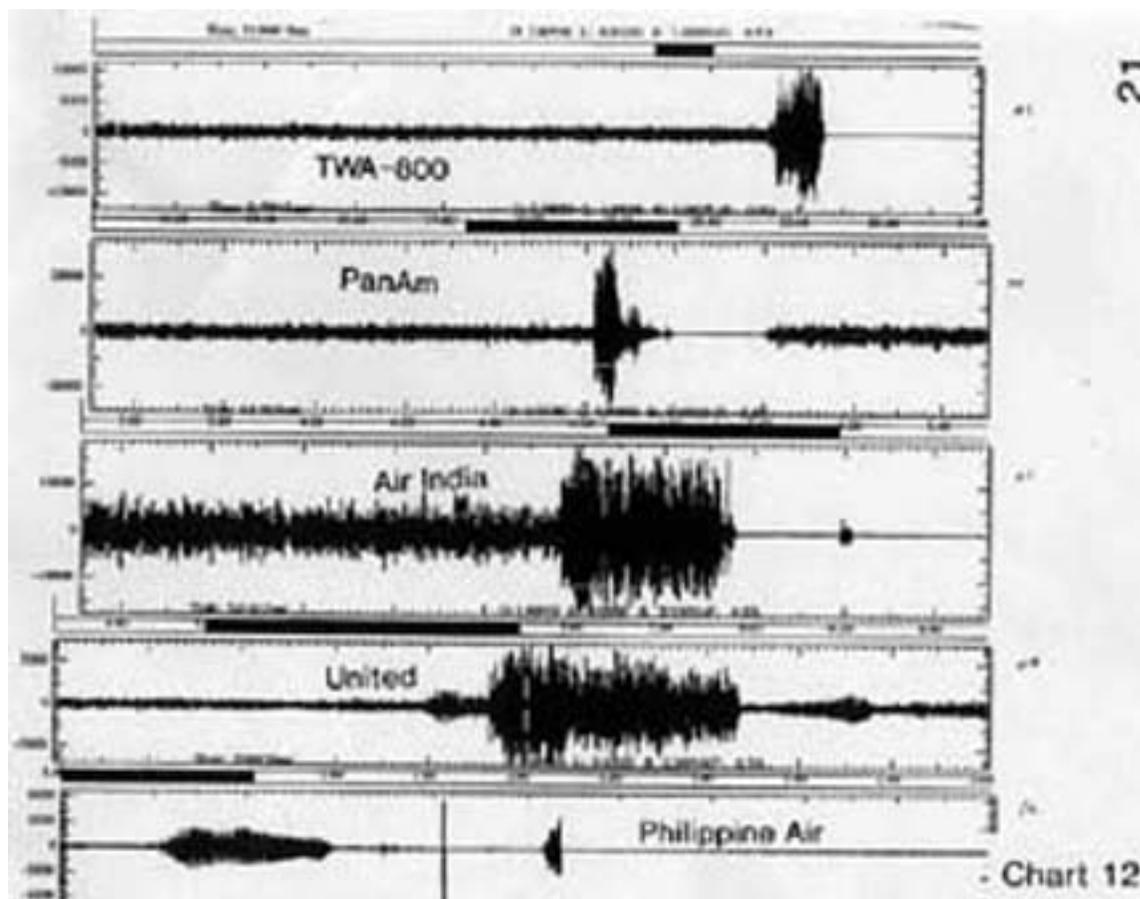


Shattered starboard side around forward cargo door of Trans World Airlines Flight 800 revealing outwardly and petaled shaped skin around aft midspan latch.



Photograph previous page/above showing outwardly and petaled shaped skin around forward midspan latch.

3. Docket Number SA-516, Exhibit No. 15C, Report Number 97-82, Section 41/42 Joint, Forward Cargo Door, "Examination of the lower lobe forward cargo door showed that all eight of the door latching cams remain attached (along with pieces of the door itself) to the pins along the lower door sill."



The CVR then recorded a very loud sound for a fraction of a second (0.117 second) on all channels immediately before the recording ended. The accident airplane's last recorded radar transponder return occurred at 2031:12, and a review of the FDR data indicated that the FDR lost power at 2031:12. '

From NTSB AAR 00/03 for Trans World Airlines Flight 800. 'The National Transportation Safety Board determines that the probable cause of the TWA flight 800 accident was an explosion of the center wing fuel tank (CWT), resulting from ignition of the flammable fuel/air mixture in the tank. The source of ignition energy for the explosion could not be determined with certainty, but, of the sources evaluated by the investigation, the most likely was a short circuit outside of the CWT that allowed excessive voltage to enter it through electrical wiring associated with the fuel quantity indication system.'

7. Forward cargo doors compared for the four aircraft, Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800.

A. United Airlines Flight 811

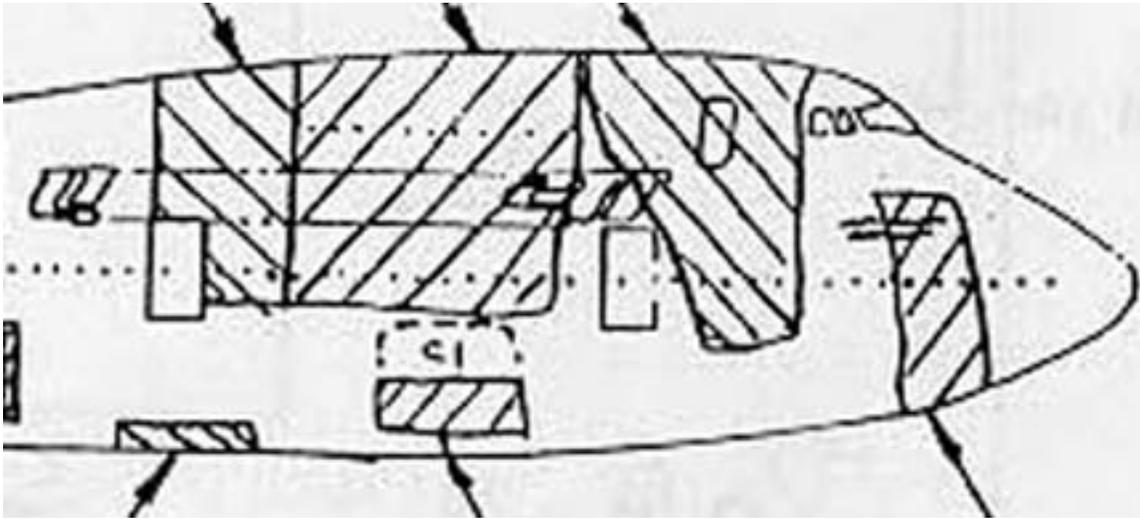




Photos from NTSB AAR 92/02 for United Airlines Flight 811 showing bottom half of the retrieved door, the longitudinal split at midspan latches, and the peeled away and down skin from the aft midspan latch.

B. Air India Flight 182. From Kirpal and CASB AAR: 2.11.4.6 Section 42

All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different than that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back onto the sea bed. An attempt to relocate the door was unsuccessful.

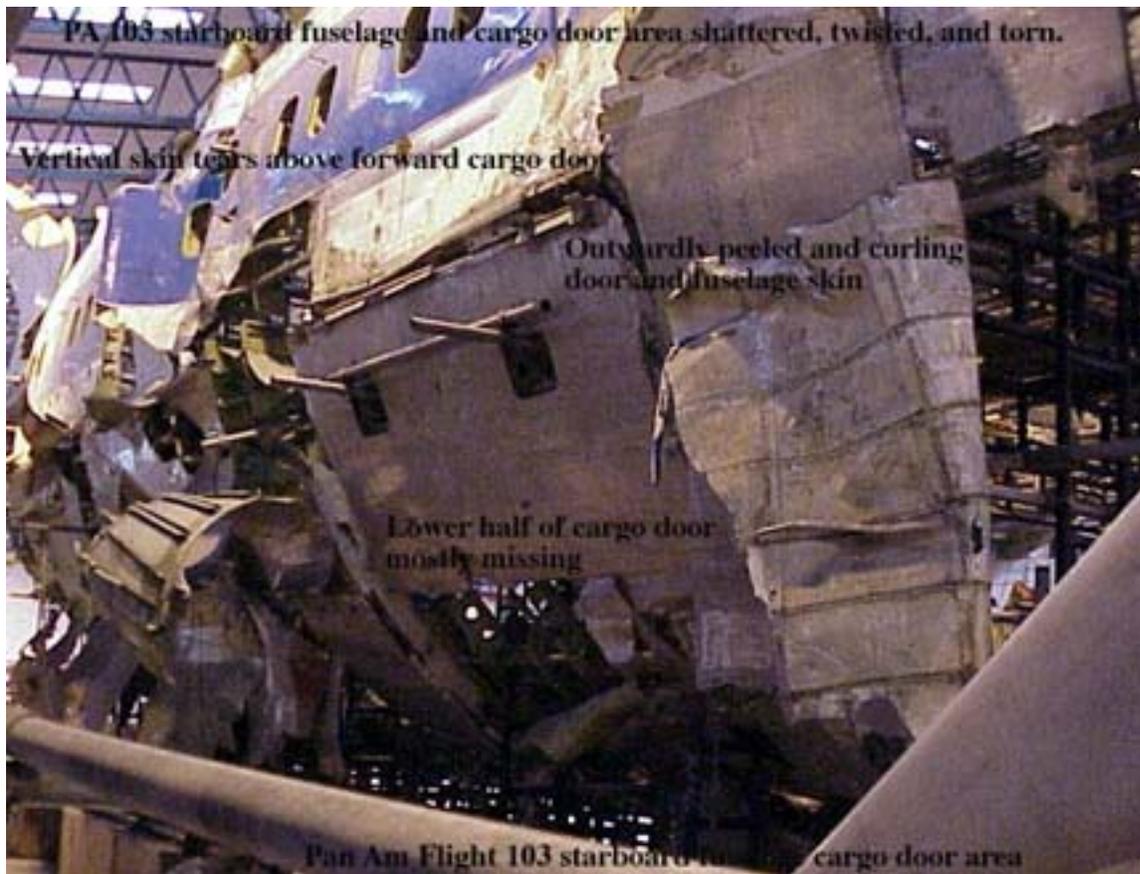


Reconstruction drawing above from the Kirpal Report and the CASB report on Air India Flight 182 showing the longitudinal split of the forward cargo door and the vertical tearing of the skin above the door.

C. Pan Am Flight 103.



Closeup of the peeled back and down skin from the aft midspan latch of PA 103 forward cargo door.



Photograph from AAIB showing Pan Am Flight 103 forward cargo door area revealing the vertical torn skin above door, peeled back and down skin from the aft midspan latch, generally shattered area, and mostly missing lower half of door which includes the manual locking handle and the eight bottom latches.

D. Trans World Airlines Flight 800



Shattered starboard side around forward cargo door of Trans World Airlines Flight 800 revealing outwardly and petaled shaped skin around aft midspan latch.

8. Conclusions:

- A. The four forward cargo door areas on the starboard side just forward of the wing on the four aircraft reveal in photographs and text outwardly peeled skin, vertical tears in fuselage skin, missing critical pieces, and a generally shattered appearance which is unlike any other damage seen in the wreckage of the four aircraft and not seen in any other hull loss of a Boeing 747.
- B. The four door areas show a rupture in flight by an outward force. The door itself appears to be at the start of the breakup. The specific location in the door that ruptures first appears to be at the midspan latches with the aft midspan latch the most likely to rupture first.
- C. The port side opposite the forward cargo door is stated in text and photographs to be relatively smooth which mitigates against a bomb explosion on the port side or a center fuel tank explosion.
- D. The shattered areas of the forward cargo door occurred at the initial event time as determined by the sudden loud sound on the cockpit voice recorder on all four aircraft. The sudden loud sound cause has been linked from Air India Flight 182 to a DC-10 explosive decompression event of an opened cargo door in flight. Pan Am Flight 103 has been linked to Air India Flight 182. Trans World Airlines Flight 800 has been linked to Pan Am Flight 103. These links establish a probable cause of the sudden loud sound as an explosive decompression when a cargo door inadvertently ruptured open in flight probably caused by faulty wiring or switch.

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**AIRCRAFT
ACCIDENT
REPORT
Pan Am Flight 103
Part IV**

Comparison between AAIB 2/90 and Smith AAR for PA 103



**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

Part IV: Comparison between AAIB 2/90 and Smith AAR for PA 103

Table of Contents:

1. Observations:

Engine number three was the only engine to fall apart from the others; it was the only one to catch fire; and it contained ingested debris from within the aircraft.

2. Observation:

Forward fuselage section was bent to starboard and then entirely detached.

3. Observations:

There are only two small fragments of plastic which are the only 'hard' evidence of a bomb (there is much evidence of an explosive decompression).

4. Observation:

The overall evidence of damage from an explosion of a powerful plastic bomb in the port side of the forward cargo hold is very limited.

5. Observation:

The sudden loud sound on the cockpit voice recorder can be linked to the explosive decompression sound of a cargo door opening in flight on an airliner.

6. Observation:

Inflight damage to the airframe of Pan Am Flight 103 does not match airframe damage from a staged bomb explosion event in a Boeing 747 at Bruntingthorpe.

7. Observations:

In the AAIB report there is a grammatical error in verb tense and irrelevant inclusions of phrases and conclusions for bomb explosion which are unsupported by evidence.

8. Observations:

There are two photographs in the AAIB report of the port 'bomb' side hole

9. Observation:

The latch status of the forward cargo door is omitted whilst the latch status of the identical aft cargo door (frames 1800-1920) and the CRAF door is given and stated as 'latched.'

10. Observation:

There is much more airframe damage on the starboard side of the airframe away from the 'bomb' explosion in areas such as the leading edge of the right wing and the right horizontal stabilizer.

11. Observation:

There was a single primary return received by both Great Dun Fell and Claxby radars approximately 16 seconds before SSR returns were lost.

12. Observation:

The aircraft, Flight PA103 from London Heathrow to New York, had been in level cruising flight at flight level 310 (31,000 feet)

13. Observation:

Pan Am Flight 103 was proceeding normally until a sudden, loud, audible sound was immediately followed by an abrupt power cut to the data recorders.

14. Observation:

The evidence of Pan Am Flight 103 was matched to Air India Flight 182 in AAIB 2/90 but not to United Airlines Flight 811.

1. Observations:

Engine number three was the only engine to fall apart from the others; it was the only one to catch fire; and it contained ingested debris from within the aircraft.

There are confusing statements in the AAIB report regarding which engines had foreign object damage:

“...it is reasonable to deduce that a manoeuvre of the aircraft occurred before most of the energy of the No 2 engine fan was lost due to the effect of ingestion (seen only in this engine.”

“...No 3 engine, identified on site as containing ingested debris from within the aircraft...”

A. Bomb explanation:

No explanation given for engine number three falling 1100 meters apart from the others. When the bomb explosion caused the 20 inch hole on the port side, the ejected debris went out and into engine number two but not serious enough to cause a fire, then went under the fuselage and into far away engine number three causing the foreign object damage and fire. The distance from bomb explosion hole to engine number two is about 27 feet aft and 30 feet outboard and the distance to engine number three is 27 feet aft and 50 feet outboard.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

The major amount of ejected material from within the cabin or baggage hold, which had opened up in the starboard side in the explosive decompression, entered the nearby engine number three causing it to catch fire. A minor amount of ejected material from the small shotgun firing hole on port side went into engine number two. The large hole where the cargo door and skin used to be caused the forward fuselage section to bend to the starboard and impact engine number three causing it to break loose and fall apart from the other three engines. No explanation given for contradiction in AAIB report on which engines ingested foreign objects and when it occurred.

C. Conclusions:

It makes little sense that foreign objects ejected from a small hole on the port side would go around the fuselage and into engine number three serious enough to cause a fire.

It makes greater sense that foreign objects from the cabin or baggage hold ejected from the very large hole on the starboard side would go into nearby engine number three; and when the larger amount of ejected material went into engine number three a normal consequence of fire ensued. When the nose bent to the starboard because of the large hole where the door and skin used to be, the forward fuselage section hit engine number three and broke it loose to land apart from the other three engines still attached to the wing.

D. AAIB Aircraft Accident Report No 2/90 (EW/C1094) quotes:

‘By similar reasoning, the absence of such shingling damage on blades of No 3 engine was a reliable indication that it suffered no ingestion until well into the accident sequence.’

‘(ii) No 3 engine, identified on site as containing ingested debris from within the aircraft, nonetheless had no evidence of the type of shingling seen on the blades of No 2 engine. Such evidence is usually unmistakable and its absence is a clear indication that No 3 engine did not suffer a major intake airflow disturbance whilst delivering significant power.

(iii) All 3 engines had evidence of blade tip rubs on the fan cases having a combination of circumference and depth greater than hitherto seen on any investigation witnessed on Boeing 747 aircraft by the Pratt and Whitney specialists. Subsequent examination of No 4 engine confirmed that it had a similar deep, large circumference tip rub. These tip-rubs on the four engines were centred at slightly different clock positions around their respective fan cases.’

‘2.5 Engine evidence The shingling damage noted on the fan blades of No 2 engine can only be attributed to airflow disturbance caused by ingestion related fan blade damage occurring when substantial power was being delivered. This is readily explained by the fact that No 2 engine intake is positioned some 27 feet aft and 30 feet outboard of the site of the explosion and that the interior of the intake exhibited a number of prominent paint smears and general foreign object damage. By similar reasoning, the absence of such shingling damage on blades of No 3 engine was a reliable indication that it suffered no ingestion until well into the accident sequence.’

‘The combination of the position of the explosive device and the forward speed of the aircraft was such that significant sized debris resulting from the explosion would have been available to be ingested by No 2 engine within milliseconds of the explosion. ...The onset of this time period would have been the time at which debris from the explosion first inflicted damage to fan blades in No 3 engine and, since the fan is only approximately 40 feet from the location of the explosive device, this would have been an insignificant time interval after the explosion.’

‘Examination of engines: The No 3 engine had fallen 1,100 metres north of the other three engines, striking the ground on its rear face, penetrating a road surface and coming to rest without any further change of orientation i.e. with the front face remaining uppermost. The intake area contained a number of loose items originating from within the cabin or baggage hold. It was not possible initially to determine whether any of the general damage to any of the engine fans or the ingestion noted in No 3 engine intake occurred whilst the relevant engines were delivering power or at a later stage.’

2. Observation:

Forward fuselage section was bent to starboard and then entirely detached.

A. Bomb explanation:

No explanation given why a 20 inch bomb shatter hole on the port side caused the forward fuselage section to bend to starboard and separate.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

A twenty foot by thirty foot hole appeared suddenly on the starboard side where the forward cargo door and skin around it used to. The large hole was too large for the fuselage to maintain structural integrity as the forward fuselage section forward of the forward cargo door bent to the starboard, hit number three engine, and the forward fuselage section separated.

C. Conclusions:

It makes little sense for a forward fuselage section to bend to the starboard and detach when the bomb exploded on the port side giving a small 20 inch hole which the aircraft is designed to withstand.

It makes greater sense that the forward fuselage section would bend into a huge hole on starboard side, lose structural integrity, and then separate.

D. AAIB Aircraft Accident Report No 2/90 (EW/C1094) Quotes:

‘1.12.3.3 General damage features not directly associated with explosive forces.

A number of features appeared to be a part of the general structural break-up which followed on from the explosive damage, rather than being a part of the explosive damage process itself. This general break-up was complex and, to a certain extent, random. However, analysis of the fractures, surface scores, paint smears and other features enabled a number of discreet elements of the break-up process to be identified. These elements are summarised below.

(v) A large, clear, imprint of semi-elliptical form was apparent on the lower right side at station 360 which had evidently been caused by the separating forward fuselage section striking the No 3 engine as it swung rearwards and to the right (confirmed by No 3 engine fan cowl damage).

(iv) The forward fuselage deflected to the right, pivoting about the starboard window belt, and then peeled away from the structure at station 800. During this process the lower nose section struck the No 3 engine intake causing the engine to detach from its pylon. This fuselage separation

was apparently complete within 3 seconds of the explosion.

(xiii) The No 3 engine detached when it was hit by the separating forward fuselage.'

3. Observations:

There are only two small fragments of plastic which are the only 'hard' evidence of a bomb. One is a fragment of circuit board (with serial number!) alleged to be part of a 'timer' of for the bomb. This fragment was discovered at an unknown time by an unknown person on a baggage container behind the container manufacturer's data plate which contained a burnt piece of material which itself contained a fragment of circuit board. The other fragment was discovered in a buckled section of the metal container by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device (IED).

A. Bomb explanation:

Bomb exploded in a metal baggage container and blew the timer to pieces which lodged in baggage container. The data plate is on the outside of the container, not the inside and no explanation given for its discovery on the outside of the container. A piece of plastic from a boom box radio-cassette player was found in the folds of the container and determined to be the bomb container holding the timer and plastic explosive. No explanation given for that determination.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

The 'timer' fragment did not get into a burnt piece of material and placed behind a data plate on the outside of the container by action of explosion or wind; it was placed there by a person and that person should be asked where and when he found the fragment and why he put it behind the manufacturer's data plate on the outside of that particular container. No explanation given for matching of fragment and container which blew up at 31000 feet.

The boom box fragment may have been a piece from a boom-box loaded into the baggage compartment by a passenger who listened to music. There is no supporting evidence that a piece of plastic from a boom box was part of a bomb or that the 'timer' fragment was inside the plastic boom box.

C. Conclusions:

It makes little sense that a bomb containing a timer (which is neither timing or altitude actuated) explodes six miles high, scatters thousands of pieces of debris to the winds, and yet a fragment of the 'timer' is found in the wreckage of the baggage container, identified as such, and placed on the outside in the correct container out of many. It makes little sense that a bomb with a timer exploded inside a suitcase inside a baggage container which then sends a fragment of the timer to lodge on the outside, not the inside, of the baggage container, which is mostly intact. It makes little sense that a piece of a boom box which can reasonably be expected to be in a baggage compartment can be determined to be a makeshift bomb with no supporting evidence.

It makes greater sense that an unknown person put the plastic fragment behind the data plate for some unknown reason and that there was a boom box in a suitcase of a passenger who listened to music.

D. AAIB Aircraft Accident Report No 2/90 (EW/C1094) quotes:

Appendix F-5, item 'c' which states, "Container manufacturer's data plate which contained a burnt piece of material which itself contained a fragment of circuit board."

‘Container Reconstruction Those parts which could be positively identified as being from containers AVE 4041 PA and AVN 7511 PA were assembled onto one of three wooden frameworks; one each for the floor and superstructure of container 4041, and one for the superstructure of container 7511. Approximately 85% of container 4041 was identified, the main missing sections being the aft half of the sloping face skin and all of the curtain.’

‘While this work was in progress a buckled section of skin from container 4041 was found by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device.’

‘Examination of all other component parts of the remaining containers from the front and rear cargo holds did not reveal any evidence of blast damage similar to that found on containers 4041 and 7511.’

4. Observation:

The overall evidence of damage from an explosion of a powerful plastic bomb in the port side of the forward cargo hold is very limited.

A. Bomb explanation:

The powerful bomb exploded and caused a series of events which are difficult to explain but did cause the forward fuselage section to come off.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

The firing of a rather large shotgun on the port side of the forward cargo compartment which may have given evidence which led investigators to conclude a powerful bomb had been detonated causing the destruction of Pan Am Flight 103. The limited damage to the fuselage skin and the baggage containers may have been caused by a rather large shotgun which fired after the nearby huge explosive decompression when the cargo door ruptured open. The evidence shows a relatively mild directed blast existed a corner of a baggage container, traveled 25 inches and caused a 20 inch hole in the fuselage skin. The sound of the mild directed blast was not heard on the cockpit voice recorder.

Bombs are loud, spherical, and powerful. Shotgun blasts are relatively mild and directed. The damage in the baggage container and adjacent area is from a mild directed blast as if a rather large shotgun had gone off at close range. The AAIB official opined the cause of the damage he/she personally viewed to be as if a rather large shotgun had been fired at the fuselage at close range. It may not have been exactly a shotgun but some other type of directed firearm.

This AAIB opinion may have been correct in its assessment of the cause of the mild blast, pitting, sooting, distortions, ragged, and shattered skin as if a very large shotgun had been fired at the inner surface of the fuselage at close range. It may be that pitting, sooting, distortions, ragged, and shattered skin could also have been interpreted as evidence of a bomb explosion.

Loaded guns have been inserted into baggage holds of airliners before and have been accidentally discharged, (April 26, 2000 Gun goes off in bag being loaded into jet. Associated Press - Portland “A high-powered handgun went off in the baggage compartment of an Alaska Airlines jetliner on the tarmac at Portland International Airport, sending a bullet into the passenger compartment within inches of passengers' feet. Nobody was injured.”)

Shotgun cartridges give sooty residue when fired. A shotgun fires in a directed manner and would give a relatively mild blast compared to a high explosive bomb. The sound of the weapon firing is not heard on the cockpit voice recorder because the power had been abruptly cut after the tremendous explosive decompression when the huge hole appeared on the starboard side of the hold or the gunshot was over shouted by the tremendous noise from the huge hole and the explosive decompression.

The evidence corroborates the firing of a device called a rather large shotgun in a baggage container which caused a relatively mild directed blast which resulted in a 20 inch hole in the fuselage skin on the port side. This damage was not sufficient to cause the forward fuselage section to come off Pan Am Flight 103 because the structure was designed to withstand a hole that size in the pressurized hull by the presences of stiffeners, ribs, and belts. In fact, a Boeing 747 can withstand a hole of nine feet by twenty feet in the nose just forward of the wing as shown by United Airlines Flight 811.

The firing of the shotgun was after the explosive decompression because the sound of the gunshot is not on the cockpit voice recorder which had had an abrupt power cut.

The location in the forward cargo compartment in the baggage container which had its lower quadrant blown away may have held a rather large shotgun which was stored in baggage, was loaded, and was safe unless a tremendous explosion happened nearby. A tremendous explosion did happen nearby when the opposite fuselage blew out when a huge twenty foot by forty foot hold appeared suddenly where the forward cargo door and skin above it used to be. The rather large shotgun fired, the relatively mild directed explosion left soot on a rib, burst through the corner of the baggage container, went 25 inches and made a 20 inch hole in the port side of the fuselage. A sooty rib was soon found on the ground and incorrectly declared proof a bomb had gone off instead of a shotgun cartridge.

C. Conclusions:

It makes little sense that a 20 inch hole in the fuselage was caused by a powerful plastic bomb and that small hole would cause the forward fuselage section of a Boeing 747 to bend to the starboard and detach.

It makes greater sense that a rather large shotgun inadvertently fired in a suitcase and caused the 20 inch hole in the skin and other sooty evidence and misled investigators to believe it was the result of a powerful plastic bomb explosion.

D. AAIB Aircraft Accident Report No 2/90 (EW/C1094) quotes:

Fuselage: "Where these panels formed the boundary of the shatter zone, the metal in the immediate locality was ragged, heavily distorted, and the inner surfaces were pitted and sooted - rather as if a very large shotgun had been fired at the inner surface of the fuselage at close range."

'Analysis: "With the two container reconstructions placed together it became apparent that a relatively mild blast had exited container 4041 through the rear lower face to the left of the curtain and impinged at an angle on the forward face of container 7511.'

'Throughout the general examination of the aircraft wreckage, direct evidence of blast damage was exhibited on the airframe only in the area bounded, approximately, by stations 700 and 720 and stringers 38L and 40L. Blast damage was found only on pieces of containers 4042 and 7511, the relative location and character of which left no doubt that it was directly associated with airframe damage.'

‘Blast damage to the forward face of container 7511 was as a direct result of hot gases/fragments escaping from the aft face of container 4041. No evidence was seen to suggest that more than one IED had detonated on Flight PA103. ‘

5. Observation:

The sudden loud sound on the cockpit voice recorder can be linked to the explosive decompression sound of a cargo door opening in flight on an airliner. The sudden loud sound has not been matched to any bomb explosion sound because of missing lower frequencies and a too slow rise time. The sudden loud sound is stated to be the initial event and is the best evidence because it is direct proof of the explosion.

A. Bomb explanation:

No explanation given why a bomb explosion sound is absent from the CVR when it must be present if it were the initial event.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

The initial event of sudden loud sound is the explosive decompression sound when the rupture/structural failure occurred and the air molecules rushed out making the sudden loud sound on the CVR. Pan Am Flight 103 has been matched to Air India Flight 182 in the AAIB report. This initial event sudden sound on the CVR for Air India Flight 182 has been matched to a DC-10 explosive decompression sound when its cargo door opened in flight. All four Boeing 747 sudden loud sound events, Air India Flight 182, Pan Am Flight 103, and United Airlines Flight 811 have been matched by NTSB in Chart 12 (Cover sheet of Part II of Smith AAR) of the public docket for Trans World Airlines Flight 800. The sound of the shotgun firing was not heard because the explosive decompression noise was louder or was because there was an abrupt power cut to the recorders after the sudden loud sound of explosive decompression.

C. Conclusions:

It makes little sense to disregard the most direct evidence of the initial event which is the sudden loud sound on the cockpit voice recorder which is not matched to a bomb explosion.

It makes greater sense to determine the sudden loud sound is the sound of the explosive decompression when the hull ruptures at the forward cargo door giving a sudden loud sound have been linked to an explosive decompression in a DC-10 cargo door event.

D. AAIB Aircraft Accident Report No 2/90 (EW/C1094) quotes:

‘Cockpit voice recorder The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual crew behaviour. The tape record ended, at 19:02:50 hrs +- second, with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording whilst the crew were copying their transatlantic clearance from Shanwick ATC.” UK AAIB Report 2/90 Page 15 It is not clear if the sound at the end of the recording is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case. UK AAIB Report 2/90 Page 38’

From the Canadian Aviation Occurrence Report: ‘2.10.2 Analysis by Accidents Investigation Branch (AIB), United Kingdom An analysis of the CVR audio found no significant very low frequency content which would be expected from the sound created by the detonation of a high explosive device. Considering the different acoustic characteristics between a DC-10 and a B747, the AIB analysis indicates that there were distinct similarities between the sound of the explosive decompression on the DC-10 and the sound recorded on the AI 182 CVR.’

6. Observation:

Inflight damage to the airframe of Pan Am Flight 103 does not match airframe damage from a staged bomb explosion event in a Boeing 747 at Bruntingthorpe.

A. Bomb explanation:

No explanation given why staged Boeing 747 bombing evidence does not match the evidence of a terrorist planned bombing of another Boeing 747, Pan Am Flight 103.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

A real bombing gives an obvious and unique signature of specific evidence. That signature was present at the Bruntingthorpe staged bombing but absent from Pan Am Flight 103 because there was no bomb explosion.

C. Conclusions:

It makes little sense to disregard a mismatch between a real bombing event and a presumed bombing event and continue to call the presumed event a bomb explosion.

It makes greater sense to determine Pan Am Flight 103 was not a bombing event because a bomb signature, such as that found at Bruntingthorpe staged bombing, was absent.

D. Quote from official at Bruntingthorpe:

"Very small amounts of explosives left very distinctive marks, unlike anything we've seen on the plane," said one investigative source, speaking of the recent tests. "Even the small amounts [of explosives] left distinctive signatures on the structures, so if a small bomb had gone off, it clearly would leave a signature."

7. Observations:

In the AAIB report there is a grammatical error in verb tense and irrelevant inclusions of phrases and conclusions for bomb explosion which are unsupported by evidence.

AAIB 2/90:

'The datum line, discussed at paragraph 1.12.1.6, was derived from a detailed analysis of the distribution of specific items of wreckage, including those exhibiting positive evidence of a detonating high performance plastic explosive.'

'The items used to define the datum line, included those exhibiting positive evidence of a detonating high performance plastic explosive, would have been the first pieces to have been released from the aircraft.'

A. Bomb explanation:

Any time an opportunity arises to declare a bomb exploded in Pan Am Flight 103 is a good time.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

The AAIB report is generally well written, precise, grammatically correct, and punctuation is perfect; however, the only two exceptions deal with statements about the 'plastic explosive'.

The text reads clearer: 'The datum line, discussed at paragraph 1.12.1.6, was derived from a detailed analysis of the distribution of specific items of wreckage.' The inclusion of the phrase, "...including those exhibiting positive evidence of a detonating high performance plastic

explosive,” is irrelevant and incongruous in context of datum lines.

And:

‘The items used to define the datum line would have been the first pieces to have been released from the aircraft.’ The inclusion of the almost identical strange phrase, “...included those exhibiting positive evidence of a detonating high performance plastic explosive,” is appended, grammatically incorrect as written, and incongruous in context of datum lines.

C. Conclusions:

It makes little sense that AAIB investigators who have written an important document which is precise and grammatically correct in most respects would make grammar errors in two sentences concerning a detonating high performance plastic explosive.

It makes greater sense that the the phrases were inserted as changes at the last minute by a non-AAIB official to bolster a weak case and the insertions were not caught by AAIB officials.

D. AAIB Aircraft Accident Report No 2/90 (EW/C1094) quotes:

‘The datum line, discussed at paragraph 1.12.1.6, was derived from a detailed analysis of the distribution of specific items of wreckage, including those exhibiting positive evidence of a detonating high performance plastic explosive. The scatter of these items about the datum line may have been due partly to velocities imparted by the force of the detonating explosive and partly by the difficulty experienced in pinpointing the location of the wreckage accurately in relatively featureless terrain and poor visibility. However, the random nature of the scatter created by these two effects would have tended to counteract one another, and a major error in any one of the eleven grid references would have had little overall effect on the whole line. There is, therefore, good reason to have confidence in the validity of the datum line.

‘The items used to define the datum line, included those exhibiting positive evidence of a detonating high performance plastic explosive, would have been the first pieces to have been released from the aircraft.’

8. Observations:

There are two photographs in the AAIB report of the port ‘bomb’ side hole just forward of the wing in the wreckage reconstruction, B-16 and B-17, and two identical artist’s impression of the port side bomb explosion on B-19 and B-24. There are no pictures of the shattered starboard, cargo door, side just forward of the wing in the wreckage reconstruction. The forward cargo door is sketched in as undamaged in B-20 and B-21 in three drawings of explosive damage which contradicts the wreckage reconstruction evidence in the photographs of the shattered forward cargo door.

A. Bomb explanation:

The only important side to look at is the bomb explosion side which is the port side with its 20 inch hole in the fuselage skin and worthy of two photographs, two identical sketches and another of an artist’s impression of the explosion. The twenty foot by thirty foot hole in the starboard side, the cargo door side, is not relevant and thus can be omitted.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

No explanation given for omission of photographs of the wreckage reconstruction of the other side of the cargo hold said to contain a powerful bomb. No explanation given for sketches of

an undamaged forward cargo door when the photographic evidence shows it shattered. Recent photographs of the forward cargo door area are very revealing and show much outward shattered skin and missing parts. The port side damage was exaggerated in sketches and the starboard side damage omitted or played down.

C. Conclusions:

It makes little sense to go to the expense of a total fuselage reconstruction and only show one side, a relatively smooth port side while omitting a shattered starboard side.

It makes greater sense that the investigators were making a case for a bomb explosion on the port side and deemed any other information which contradicted that conclusion as irrelevant and distracting and thus omitted.

D. AAIB Aircraft Accident Report No 2/90 (EW/C1094) quotes:

‘To facilitate this additional work, wreckage forming a 65 foot section of the fuselage (approximately 30 feet each side of the explosion) was transported to AAIB Farnborough, where it was attached to a specially designed framework to form a fully three-dimensional reconstruction [Appendix B, Figures B-16 and B-17] of the complete fuselage between stations 360 & 1000 (from the separated nose section back to the wing cut out). The support framework was designed to provide full and free access to all parts of the structure, both internally and externally.’

9. Observation:

The latch status of the forward cargo door is omitted whilst the latch status of the identical aft cargo door (frames 1800-1920) and the CRAF door is given and stated as ‘latched.’

A. Bomb explanation:

The latch status of the forward cargo door is unimportant as it was not involved in any way with the bomb explosion and thus omitted.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

The assumption must be made that the latch status of the forward cargo door was ‘unlatched’ or ‘unknown,’ since, if it were latched, it would have been reported as same.

No explanation given for the omission in the report of the latch status of a cargo door which is known to have failed before, is a complex device prone to airworthiness directives, and was very near the site of the ‘bomb’ explosion.

C. Conclusions:

It makes little sense to omit such vital information about a complex device that has failed before which could cause a hull rupture inflight if it had failed again.

It makes greater sense that the information was omitted because it conflicted with the official conclusions of a bomb explosion and thus deemed unimportant.

D. AAIB Aircraft Accident Report No 2/90 (EW/C1094) quotes:

‘The CRAF door itself (latched) apart from the top area containing the hinge;’

‘Other items found in the wreckage included both body landing gears, the right wing landing gear, the left and right landing gear support beams and the cargo door (frames 1800-1920) which was latched.’

10. Observation:

There is much more airframe damage on the starboard side of the airframe away from the

'bomb' explosion in areas such as the leading edge of the right wing and the right horizontal stabilizer.

A. Bomb explanation:

The ejected material and skin from the post side bomb explosion went out, aft, and over the fuselage then impacted the starboard side wing and tailplane. The bomb energy spread out and through the aircraft gaining power and blew out the faraway sections of skin although it was not possible to find a specific mechanism for the damage.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

The more severe starboard side fuselage, tail, and wing damage was caused by the tremendous explosive decompression on the starboard side of the fuselage just forward of the wing in the forward cargo door area. The evidence of localised skin separation and peel-back is from the explosive decompression forces, not the relatively mild blast from the 'bomb explosion.'

C. Conclusions:

It makes little sense that a small 20 inch hole on the port side could cause the severe damage on the starboard side of the airframe or that material from the port side of the aircraft travels out, over, and aft of the fuselage and impacts on the starboard side of the tailplane.

It makes greater sense that the more severe airframe localised skin separation and peel-back inflight damage on the starboard side is because of the massive ejected material and torn away skin from the forward cargo door area on the starboard side of the airframe from the explosive decompression that ejected material out and directly aft into the right wing leading edge, engine number three and right horizontal stabilizer.

D. AAIB Aircraft Accident Report No 2/90 (EW/C1094) quotes:

'Whilst it has not been possible to find a specific mechanism to explain the regions of localised skin separation and peel-back (i.e. the 'pressure blow' regions referred to in para 2.12.2), they were almost certainly the result of high intensity shock overpressures produced locally in those regions as a result of the additive recombination of shock waves transmitted through the lower hull cavities. It is considered that the relatively close proximity of the left side region of damage just below floor level at station 500, [Appendix B, Figure B-19, region D] to the forward end of the cargo hold may be significant insofar as the reflections back from the forward end of the hold would have produced a local enhancement of the shock overpressure. Similarly, 'end blockage effects' produced by the cargo door frame might have been responsible for local enhancements in the area of the belly skin separation and curl-back at station 560.'

'(iv) The fuselage left side lower lobe from station 740 back to the wing box cut-out, and from the window level down to the cargo deck floor (the fracture line along stringer 38L), had peeled outwards, upwards and rearwards - separating from the rest of the fuselage at the window belt. The whole of this separated section had then continued to slide upwards and rearwards, over the fuselage, before being carried back in the slipstream and colliding with the outer leading edge of the right horizontal stabiliser, completely disrupting the outer half.'

'The right tailplane exhibited massive leading edge impact damage on the outboard portion which also appeared to have progressed to disruption of the aft torsion box. A fragment of right tailplane spar cap was found embedded in the fuselage structure adjacent to the two vent valves, just below, and forward of, the L2 door and it is clear that this area of forward left fuselage had travelled over the top of the aircraft and contributed to the destruction of the outboard right tailplane.'

11. Observation:

There was a single primary return received by both Great Dun Fell and Claxby radars approximately 16 seconds before SSR returns were lost. The return was only present for one point and no explanation can be offered for its presence. It is displayed as a green diamond in Figures C-15 through C-23 in the AAIB Report 2/90.

A. Bomb explanation:

No explanation given for radar returns shown as green diamond. Information was disregarded.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

One primary target on one radar may be an artifact. Two targets on two radars may be a coincidence. Two targets on two radars at the same time and at the same place is a real target which means a large piece of metal reflected radar energy to two radars.

The explanation offered for its presence is of the lower half of the forward cargo door rupturing outward and spinning away in the night. The angles of the spinning metal skin were such to only return energy to two radars on only one sweep. A precedent was set of surveillance radars picking up pieces of cargo door spinning away in flight has been set by United Airlines Flight 811.

C. Conclusions:

It makes little sense for a genuine primary radar target to appear just before the destruction of a large airliner and for that target information to be disregarded.

It makes greater sense that when the lower half of the forward cargo door ruptured open in flight and ejected the door pieces and fuselage skin into the air that two radars picked up the reflections from the spinning metal skin and the target appeared on the radar scopes at the same time at the same location.

D. AAIB Aircraft Accident Report No 2/90 (EW/C1094) quotes:

'Recorded radar information: Recorded radar information on the aircraft was available from from 4 radar sites. Initial analysis consisted of viewing the recorded information as it was shown to the controller on the radar screen, from this it was clear that the flight had progressed in a normal manner until Secondary Surveillance Radar (SSR) was lost. There was a single primary return received by both Great Dun Fell and Claxby radars approximately 16 seconds before SSR returns were lost. The Lowther Hill and St. Annes radars did not see this return. The Great Dun Fell radar recording was watched for 1 hour both before and after this single return for any signs of other spurious returns, but none was seen. The return was only present for one point and no explanation can be offered for its presence.'

12. Observation:

The aircraft, Flight PA103 from London Heathrow to New York, had been in level cruising flight at flight level 310 (31,000 feet) for approximately seven minutes when the last secondary radar return was received just before 19.03 hrs. The radar then showed multiple primary returns fanning out downwind.

A. Bomb explanation:

A bomb was placed in a Boeing 727 which took off from Malta and flew to Frankfurt Germany without the bomb going off. The plane then flew to London without the bomb going off. The bomb was transferred to a Boeing 747 which took off and then the bomb went off. The timer was thus not an altitude timer nor a timing timer but a timer of unknown type.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

The explosion occurred soon after the highest pressure differential was reached, 8.9 PSI at 31000 feet MSL, when the midspan latches ruptured open the forward cargo door. There was no bomb and there was no timer and there was no bomb explosion but there was something that looked, smelled, and sounded like a bomb explosion, but wasn't. It was a tremendous explosion of an explosive decompression from a hull rupture at a door. There was something that looked like a rather large shotgun had gone off in a baggage container and it probably was and it probably did which led investigators to assume a bomb explosion had occurred.

C. Conclusions:

It makes little sense for a bomb to be placed aboard an aircraft which flies and flies without detonating and then the bomb is transferred to another plane which explodes later by some unknown type of timer.

It makes greater sense that an explosive decompression occurred, which mimics a bomb explosion, at the highest pressure differential in the hull soon after takeoff and cruise established.

D. AAIB Aircraft Accident Report No 2/90 (EW/C1094) quotes:

None regarding the several flights of the bomb in two aircraft in three airports in three countries before it detonated.

13.Observation:

Pan Am Flight 103 was proceeding normally until a sudden, loud, audible sound was immediately followed by an abrupt power cut to the data recorders.

A. Bomb explanation:

The bomb explosion cut the power to the recorders.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

The tremendous explosive decompression explosion cut the power to the recorders in the adjacent main equipment compartment abruptly after the sudden loud sound of the air rushing out of the forward cargo compartment was picked up on the cockpit voice recorders.

C. Conclusions:

It makes little sense that a relatively mild explosion which caused a 20 inch hole in the fuselage skin would cause an abrupt power cut to the recorders when the aircraft is designed to easily withstand such an event.

It makes greater sense that a tremendous explosive decompression would cause an abrupt power cut to the recorders in the adjacent compartment.

D. AAIB Aircraft Accident Report No 2/90 (EW/C1094) quotes:

'Digital flight data recordings The analysis of the recording from the DFDR fitted to N739PA, showed that the recorded data simply stopped. Following careful examination and correlation of the various sources of recorded information, it was concluded that this occurred because the electrical power supply to the recorder had been interrupted at 19:02:50 +- second. UK AAIB Report 2/90 Page 37 The analysis of the cockpit voice recording, which is detailed in Appendix C, concluded that there were valid signals available to the DVR when it stopped at 19:02.50 +- second because the power supply to the recorder was interrupted. It is not clear if the sound at the end of the recording is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical

power suggests that the latter is more likely to be the case. UK AAIB Report 2/90 Page 38

14. Observation:

The evidence of Pan Am Flight 103 was matched to Air India Flight 182 in AAIB 2/90 but not to United Airlines Flight 811.

A. Bomb explanation:

Air India Flight 182 was deemed a bomb explosion by the Indian judicial authorities. Since Pan Am Flight 103 was determined early on to be a bomb explosion, only that flight information was relevant and thus compared and included in AAIB 2/90.

B. Shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation:

No explanation given why the evidence of United Airlines Flight 811 with much similar evidence to Pan Am Flight 103 was not matched to Pan Am Flight 103 as well as Air India Flight 182 in AAIB 2/90.

Both United Airlines Flight 811 and Pan Am Flight 103 were:

Aged.

High flight time.

Early model-100.

Poly x wired.

Boeing 747.

Experienced hull rupture forward of the wing on right side in cargo door area.

Shape of hull rupture forward of the wing on the right side is rectangle with specific rectangular shape.

Fodded number three engine.

On fire number three engine.

Sudden sound on CVR

Loud sound on the CVR.

Short duration sound on the CVR.

Abrupt power cut to FDR.

Outwardly peeled and down skin in cargo door area from aft midspan latch.

Longitudinal break at midline of the forward cargo door at midspan latch.

More severe inflight damage on starboard side.

At least nine never recovered bodies.

Vertical fuselage tear lines forward of the wing and aft of cargo door.

Torn off and missing skin in forward cargo door area on starboard side.

Outward peeled skin on upper forward fuselage.

Destruction initially thought to be have been caused by a bomb.

C. Conclusions:

It makes little sense to ignore closely matching evidence of Pan Am Flight 103 to another similar event of United Airlines Flight 811 while including an accident with inconclusive findings, Air India Flight 182.

It makes greater sense to compare Pan Am Flight 103 to United Airlines Flight 811 as well as Air India Flight 182. (Trans World Airlines Flight 800 had not yet occurred.)

D. AAIB Aircraft Accident Report No 2/90 (EW/C1094) quotes:

'Detection of explosive occurrences: In the aftermath of the Air India Boeing 747 accident (AI 182) in the North Atlantic on 23 June 1985, RARDE were asked informally by AAIB to

examine means of differentiating, by recording violent cabin pressure pulses, between the detonation of an explosive device within the cabin (positive pulse) and a catastrophic structural failure (negative pulse).’

15. Conclusions:

Pan Am Flight 103 occurred before United Airlines Flight 811 and Trans World Airlines Flight 800 and after Air India Flight 182.

The AAIB Aircraft Accident Report No 2/90 (EW/C1094) report reflects the sentiment of the times in the late 1980s that terrorists were everywhere and were blowing up airplanes at will. The determination was made within days of the inflight breakup that the cause was probably a bomb explosion and efforts were directed toward catching the culprits. A precedent has been set by the Indian government who declared that the similar accident, Air India Flight 182, was caused by a bomb explosion in the forward cargo hold, although the Canadians refused to state the cause of that explosion. A mechanical explanation for Pan Am Flight 103, such as that of United Airlines Flight 811, was given very little consideration.

The AAIB investigators did not have the luxury of hindsight to learn the lessons of Trans World Airlines Flight 800 nor did they take advantage of the lessons of United Airlines Flight 811 which occurred a short two months later after Pan Am Flight 103.

The writers of the AAIB report struggled to explain how a relatively mild directed blast on the port side of the forward cargo compartment caused outward ruptures faraway from the shatter zone, caused foreign object damage in an engine far away, caused inflight damage to an opposite side horizontal stabilizer, and caused much more damage throughout the starboard side of the airframe. They stretched with explanations such as the ejected material did strange things by going over, around, and under the fuselage to get to the affected areas. They brought in a theory of Mach Stem which presents the novel idea that a mild blast which disseminates through ducts and baggage containers actually manages to gain enough energy to do more damage faraway even as the energy is being absorbed by suitcases, baggage containers, and floor panels.

The writers ignored the logical questions of how a mild blast on the port side could have caused such a large hole opposite on the starboard side at initial event time; why the forward section buckled to the starboard instead of the port side; why was the sound of a powerful bomb not heard on the cockpit voice recorder; how a mild blast abruptly shut off the entire power supply to the aircraft, and how a piece of timer of a bomb which exploded high up shows up inexplicably tucked in behind a plate on the outside of a baggage container.

Only photographs of the port side are revealed, no text explanations are given to the starboard side opposite, sketches of the cargo door are inaccurate while the port side sketches are exaggerated. The writers generally ignored the starboard side of the wreckage reconstruction although it showed more damage than the port and all of the inflight damage to engine number three, right wing, and right horizontal stabilizer would be easily explained if the explosion had occurred on the starboard side.

The AAIB report reads more like a prosecution case for a crime of a terrorist bombing than an objective investigative aircraft accident report. In fact, one could say the report doth protest too much that it was a bomb explosion. (As one might say the Smith AAR doth protest too much it was a wiring/cargo door event.)

The precision of the English language was put to good use by the conclusions reached of an

“Improvised Explosive Device’ instead of a “Bomb’ since the evidence did show an improvised explosive device and not a bomb explosion, although the intent was for the reader to believe it was a bomb explosion. To this day, officials continue to call the object which started the destruction a ‘device’ and not a ‘bomb’.

Mechanical alternatives were not given due consideration after the first few days when a sooty and pitted rib was found in the wreckage. There is very little information in the AAIB report about possible alternatives such as a center fuel tank explosion, hull rupture by structural failure, or explosive decompression by a mechanical source such as inadvertently opened cargo door or cargo shift.

Since major aircraft accidents now have international repercussions, politics which reflects the popular will of the moment takes precedence over objective investigations conducted in a calm and thoughtful manner. Extreme pressure was put on all investigative authorities from law enforcement to aviation accident investigators for a quick answer to the cause of Pan Am Flight 103. A popular answer was that the cause was not the fault of the manufacturer, the airline, or the government oversight agencies but was the fault of evil terrorists who had managed to slip by inadequate security. The direction of the investigation was set; a crime of a bombing and find the perpetrators.

The result is AAIB Aircraft Accident Report No 2/90, written fifteen months after Pan Am Flight 103 suffered the inflight breakup which appeared to be caused by a bomb, was assumed to be a bomb explosion, and almost all of the report describes what happened after the bomb went off on the port side of the forward cargo compartment. To this day, it is assumed a bomb exploded in Pan Am Flight 103 and the only disagreements are who put it there, when, and why.

The conclusion reached by this investigator in this AAR is that there was no bomb in Pan Am Flight 103. There was no bomb explosion. There was something that looked like a bomb explosion but wasn't. The evidence revealed by subsequent similar accidents indicates that there was a tremendous explosion of an explosive decompression when the forward cargo door ruptured open inflight, probably at the midspan latches and probably caused by faulty wiring or switch.

Respectfully submitted;

John Barry Smith
Independent Aircraft Accident Investigator
1 May 2002,
Carmel Valley, California

**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

**Appendix A: Boeing 747 Accidents
(Unofficial 1970 through 1997) Harro Ranter**

Following is a listing of all Boeing 747 aircraft, damaged beyond repair in accidents.

1) 06.09.70 () Boeing 747-121 N752PA (19656/34) Pan American World Airways 0 fatalities / 0 occupants +

Location: Cairo IAP (Egypt) Nature: Scheduled Passenger Phase: Ground from: Amsterdam-Schiphol APT to: New York-John F. Kennedy IAP Flightnr.: PA93 The aircraft was hijacked by two men just after leaving Amsterdam. The flight diverted to Beirut, where 7 others boarded the plane. The aircraft was flown to Cairo. All occupants were released and the aircraft was blown up. Source: Aircraft hijackings and other criminal acts against civil aviation : statistics and narrative reports / FAA

2) 23.07.73 () Boeing 747-246B

JA-8109 (20503/180) Japan Air Lines - JAL 0 fatalities / 0 occupants +

Location: Benghazi-Benina (Libya) Nature: Scheduled Passenger Phase: Ground from: Amsterdam-Schiphol APT to: Anchorage IAP Flightnr.: JA404 Flight 404 was hijacked by 4 men and a woman, shortly after leaving Amsterdam. The woman hijacker got killed in an accidental explosion of the explosive device she was carrying. The aircraft landed at Dubai and later took off for Damascus and Benghazi. All passengers and crew were released and the aircraft blown up.

3) 20.11.74 (ca. 07:50) Boeing 747-130

D-ABYB (19747/29) Lufthansa

59 fatalities / 157 occupants +

Location: Nairobi-Wilson APT (Kenya) Nature: Scheduled Passenger Phase: Take-off from: Nairobi-Wilson APT to: Johannesburg-Jan Smuts APT Flightnr.: LH540 Boeing 747 D-ABYB was taking off for the last leg of the Frankfurt-Nairobi- Johannesburg flight when the crew felt vibration or buffeting following lift off. The captain, suspecting wheel imbalance, raised the gear. A lack of acceleration forced the crew to lower the nose in order to maintain airspeed. The Boeing continued to descend however and contacted the ground 1120m past the end of Runway 24 and struck an elevated road 114m further on. The aircraft broke up and caught fire before coming to rest 454m past the initial point of impact. PROBABLE CAUSE: "The accident was caused by the crew initiating a take-off with the leading edge flaps retracted because the pneumatic system which operates them had not been switched on. This resulted in the aircraft becoming airborne in a partially stalled condition which the pilots did not identify in the short time available to them for recovery. Major contributory factors were the lack of warning of a critical condition of leading edge flap position and the failure of the crew to complete satisfactorily their checklist items."

4) 12.06.75 () Boeing 747-128

N28888 (20542/201) Air France

0 fatalities / 394 occupants +

Location: Bombay (India) Nature: Scheduled Passenger Phase: Take-off from: Bombay to: Flightnr.: During a 180o turn at the beginning of Runway 27 the No.11 tire (on the right hand

maingear) failed. During take-off the no.12 tire also failed. Wheels and braking assembly then started rubbing the runway, causing a fire. The take-off was aborted. Initial delay in shutting down the engines and an improper deployment of fire services caused the fire to spread.

5) 09.05.76 () Boeing 747-131F

5-8104 (19677/73) Islamic Republic of Iran Air Force 17 fatalities / 17 occupants +

Location: Madrid; nr (Spain) Nature: Freight Phase: Descent from: to: Madrid-Torrejon AFB Flightnr.: ULF48 The aircraft was struck by lightning while descending through FL100 on its way to Torrejon AFB. The explosion in the no.1 fuel tank which followed caused severe damage to the left wing. 54 Seconds later the left wing failed and freighter crashed. POSSIBLE CAUSE: Ignition of fuel vapour in the ullage of the tank in the vicinity of a motor drive fuel valve. Source: FI 15.5.76(1283)

6) 27.03.77 (17.06) Boeing 747-121

N736PA (19643/11) Pan American World Airways 335 fatalities / 396 occupants + 248

Location: Tenerife (Spain) Nature: Non Scheduled Passenger Phase: from: Tenerife-Norte Los Rodeos to: Las Palmas Flightnr.: PA1736 At 12.30h a bomb explodes in the Las Palmas passenger terminal. Because of warnings of a possible second bomb, the airport was closed. A large number of flights were diverted to Tenerife, a.o. KLM Flight 4805 from Amsterdam and PanAm Flight 1736 (coming from Los Angeles and New York). Las Palmas Airport opened to traffic again at 15.00h. Because the PanAm passengers remained on aboard it was possible to leave Tenerife at once. The taxiways were congested by other aircraft however. This meant the PanAm crew had to backtrack on Runway 12 for take-off on Runway 30. The entrance to Runway 12 however, was blocked by the KLM Boeing. The PanAm flight had to wait for almost 2 hours before all KLM passengers (except 1) had reboarded and refuelling had taken place. The KLM flight was then cleared to backtrack Runway 12 and make a 180deg. turn at the end. Three minutes later (at 17.02h) Pan Am 1736 was cleared to follow the KLM aircraft and backtrack Runway 12. The PanAm crew were told to leave the runway at the third taxiway and report leaving the runway. At 17.05:44h KLM 4805 reported ready for take-off and was given instructions for a Papa beacon departure. The KLM crew repeated the instructions and added "We are now at take-off". The brakes were released and KLM 4805 started the take-off roll. Tenerife tower, knowing that Pan Am 1736 was still taxiing down the runway replied "OK Stand by for take-off, I will call you." This message coincided with the PanAm crew's transmission "No ... uh we're stil taxiing down the runway, the Clipper 1736". These communications caused a shrill noise in the KLM cockpit, lasting approx. 3.74 seconds. Tenerife tower replied: "Papa Alpha 1736 report runway clear.", were upon the PanAm crew replied: "OK, will report when we're clear". This caused some concerns with the KLM flight engineer asking the captain: "Is he not clear then?" After repeating his question the captain answers emphatically: "Oh, yes". A number of second before impact the KLM crew saw the PanAm Boeing still taxiing down the runway. The crew tried to climb away and became airborne after a 65ft taildrag in an excessive rotation. The PanAm crew immediately turned the aircraft to the right and applied full power. The KLM aircraft was airborne, but the fuselage skidded over the PanAm's aft fuselage, destroying it and shearing off the tail. The KLM aircraft flew on and crashed out of control 150m further on, sliding another 300m bursting into flames. PROBABLE CAUSE: "The KLM aircraft had taken off without take-off clearance, in the absolute conviction that this clearance had been obtained, which was the result of a misunderstanding between the tower and the KLM aircraft. This misunderstanding had arisen from the mutual use of usual terminology which, however, gave rise to misinterpretation. In combination with a number of other coinciding circumstances, the premature take-off of the KLM aircraft resulted in a collision with the Pan Am aircraft, because the latter was still on the runway since it had missed the correct intersection."

Source: Flight Safety Digest July 1995(1-10)/Flight Safety Foundation; ICAO Circular 153-AN/56

(p.22-68) Human factors report on the Tenerife accident / Air Line Pilots Association (ALPA)

7) 27.03.77 (17.06) Boeing 747-206B

PH-BUF (20400/157) KLM Royal Dutch Airlines 248 fatalities / 248 occupants + 335

Location: Tenerife (Spain) Nature: Non Scheduled Passenger Phase: Take-off from: Tenerife-Norte Los Rodeos to: Las Palmas Flightnr.: KL4805 At 12.30h a bomb explodes in the Las Palmas passenger terminal. Because of warnings of a possible second bomb, the airport was closed. A large number of flights were diverted to Tenerife, a.o. KLM Flight 4805 from Amsterdam and PanAm Flight 1736 (coming from Los Angeles and New York). Las Palmas Airport opened to traffic again at 15.00h. Because the PanAm passengers remained on board it was possible to leave Tenerife at once. The taxiways were congested by other aircraft however. This meant the PanAm crew had to backtrack on Runway 12 for take-off on Runway 30. The entrance to Runway 12 however, was blocked by the KLM Boeing. The PanAm flight had to wait for almost 2 hours before all KLM passengers (except 1) had reboarded and refuelling had taken place. The KLM flight was then cleared to backtrack Runway 12 and make a 180deg. turn at the end. Three minutes later (at 17.02h) Pan Am 1736 was cleared to follow the KLM aircraft and backtrack Runway 12. The PanAm crew were told to leave the runway at the third taxiway and report leaving the runway. At 17.05:44h KLM 4805 reported ready for take-off and was given instructions for a Papa beacon departure. The KLM crew repeated the instructions and added "We are now at take-off". The brakes were released and KLM 4805 started the take-off roll. Tenerife tower, knowing that Pan Am 1736 was still taxiing down the runway replied "OK Stand by for take-off, I will call you." This message coincided with the PanAm crew's transmission "No ... uh we're stil taxiing down the runway, the Clipper 1736". These communications caused a shrill noise in the KLM cockpit, lasting approx. 3.74 seconds. Tenerife tower replied: "Papa Alpha 1736 report runway clear.", where upon the PanAm crew replied: "OK, will report when we're clear". This caused some concerns with the KLM flight engineer asking the captain: "Is he not clear then?" After repeating his question the captain answers emphatically: "Oh, yes". A number of second before impact the KLM crew saw the PanAm Boeing still taxiing down the runway. The crew tried to climb away and became airborne after a 65ft taildrag in an excessive rotation. The PanAm crew immediately turned the aircraft to the right and applied full power. The KLM aircraft was airborne, but the fuselage skidded over the PanAm's aft fuselage, destroying it and shearing off the tail. The KLM aircraft flew on and crashed out of control 150m further on, sliding another 300m bursting into flames. PROBABLE CAUSE: "The KLM aircraft had taken off without take-off clearance, in the absolute conviction that this clearance had been obtained, which was the result of a misunderstanding between the tower and the KLM aircraft. This misunderstanding had arisen from the mutual use of usual terminology which, however, gave rise to misinterpretation. In combination with a number of other coinciding circumstances, the premature take-off of the KLM aircraft resulted in a collision with the Pan Am aircraft, because the latter was still on the runway since it had missed the correct intersection."

Source: Flight Safety Digest July 1995(1-10)/Flight Safety Foundation; ICAO Circular 153-AN/56 (p.22-68) Human factors report on the Tenerife accident / Air Line Pilots Association (ALPA)

8) 01.01.78 (ca. 20:15) Boeing 747-237B VT-EBD (19959/124) Air India

213 fatalities / 213 occupants +

Location: Arabian Sea, off Bandra (India) Nature: Scheduled Passenger Phase: Climb from: to: Dubai IAP Flightnr.: AI855 The aircraft left Bombay-Santa Cruz Airport for a flight to Dubai (Flight AI855). Following a right turn, the aircraft rolled to the left beyond 90o, lost control and crashed into shallow (10m deep) water, 3km offshore at an angle of 35-40o. PROBABLE CAUSE: The Attitude Director Indicator (ADI) probably malfunctioned during the right turn, which led to a complete loss of situational awareness of the crew members.

9) 19.11.80 () Boeing 747-2B5B

HL-7445 (21773/366) Korean Air Lines - KAL 14 fatalities / 212 occupants +

Location: Seoul-Kimpo IAP (Korea) Nature: Scheduled Passenger Phase: Landing from: to: Seoul-Kimpo IAP Flightnr.: The aircraft struck a 45o embankment slope 2.4m from the top, crashed on Runway 14, broke up and caught fire. Weather at the time of the accident was a visibility 1000m, fog, temperature 2deg.

10) 04.08.83 () Boeing 747-121

N738PA (19645/14) Pan American World Airways 0 fatalities / 243 occupants +

Location: Karachi IAP (Pakistan) Nature: Scheduled Passenger Phase: Landing from: to: Karachi IAP Flightnr.: The aircraft touched down on a wet runway and reverse thrust was applied on all engines, except no.4 (of which the reverser had been de-activated). When coming out of reverse, the no.4 engine reached 1.4199 EPR, causing the Boeing th yaw to the left and depart the runway 2400m past the threshold. PROBABLE CAUSE: Inadvertent application of power on the no.4 engine while coming out of reverse.

11) 01.09.83 (18.26) Boeing 747-230B

HL-7442 (20559/186) Korean Air Lines - KAL 269 fatalities / 269 occupants +

Location: Okhotsk Sea () Nature: Scheduled Passenger Phase: Cruise from: Anchorage IAP, AK to: Seoul-Kimpo IAP Flightnr.: KE007 The Boeing arrived at Anchorage at 03.30 local time after a flight from New York. At 05.00h the aircraft took off again from Runway 32, bound for Seoul. The flight was cleared directly to the Bethel VOR beacon and then on to the Romeo 20 route. However, the aircraft started diverging from it's intended course and passed 12mls North of the Bethel beacon. While approaching the Kamchatka peninsula, 6 MiG-23 fighters were scrambled. Because a US Boeing RC-135 intelligence plane was flying in the area East off Kamchatka, the Soviet defence forces probably thought the B747 radar echo to be the RC-135. KAL 007 left Russian airspace over the Okhostk Sea and the fighters returned to their base. Passing abeam the Nippi beacon (4hrs after take-off), the aircraft was 185mls off course and headed for Sakhalin. Two Soviet Sukhoi Su-15 fighters were scrambled from the Dolinsk-Sokol airbase at 17.42h UTC and 17.54 respectively. At 18.16h UTC flight 007 re-entered Soviet airspace. At 18.22h the Soviet command ordered destruction of the target (for the 2nd time). Two air-to-air missiles were launched by one of the fighters and struck the Boeing at 18.26h. Cabin pressure was lost and the aircraft suffered control problems, causing the Boeing to spiral down and crash into the sea.

12) 27.11.83 (00.06) Boeing 747-283B

HK-2910 (21381/311) Avianca

181 fatalities / 192 occupants +

Location: Madrid-Barajas APT; 12km SE (Spain) Nature: Scheduled Passenger Phase: Final Approach from: Paris-Charles de Gaulle to: Madrid-Barajas Flightnr.: AV011 Avianca Flight 011 took off from Paris-Charles de Gaulle at 22.25h for a flight to Bogota via Madrid. The crew intercepted the ILS (for an approach to Runway 33) on the wrong track and continued to descend below MDA. This led to some problems with inserting the Madrid VOR coordiantes in the aircraft's INS (inertial navigation system), which caused the pilot to initiate a right turn short of the VOR beacon (the point were he should have made the turn). The right maingear and no.4 engine suddenly contacted a hill at an altitude of 2247ft and a speed of 142kts. Three seconds later the aircraft impacted a second hill at a sped of 135kts and a 4,9deg. nose-up attitude. Six seconds after contacting the 2nd hill, the aircraft (at 126kts) hit the ground with the right wing, which broke off. The Boeing cartwheeled and broke in five pieces and came to rest upside down. PROBABLE CAUSE: "The pilot-in-cormnand, without having any precise knowledge of his position, set out to intercept the ILS on an incorrect track without initiating the published instrument approach manoeuvre; in so doing he descended below all; the area safety minima until he collided with the

ground. Contributory factors were: a) Inaccurate navigation by the crew, which placed them in an incorrect position for initiating the approach manoeuvre.; b) Failure of the crew to take corrective action in accordance with the operating instructions of the ground proximity warning system.; c) Deficient teamwork on the flight deck.; d) Imprecise position information supplied to the aircraft by APP.; e) The APP controller, in failing to inform the aircraft that radar service had terminated, did not maintain a proper watch on the radar scope." (Accident Investigation Board, Spain) Source: ICAO Circular 196-AN/119 (105-107, incomplete)

13) 16.03.85 () Boeing 747-3B3

F-GDUA (22870/573) Union de Transportes Ariens - UTA 0 fatalities / 0 occupants +
Location: Paris-Charles de Gaulle (France) Nature: Phase: Ground from: - to: - Flightnr.:
Destroyed by fire.

14) 23.06.85 (07.15 GMT) Boeing 747-237B VT-EFO (21473/330) Air India

329 fatalities / 329 occupants +
Location: Atlantic Ocean () Nature: Scheduled Passenger Phase: Cruise from: Montreal-Mirabel IAP to: London-Heathrow APT Flight nr.: AI182 The aircraft left Toronto almost 2 hours late due to the installation of a 5th spare engine, fitted below the left wing. The engine had to be ferried for repairs in India. After a stopover at Montreal, Flight 182 continued to London. At 07.15h GMT the aircraft suddenly disappeared from radar screens. An explosion had occurred at FL310, causing a rapid decompression, followed by an inflight break-up. The aircraft crashed into the 2000m deep ocean off Shannon. PROBABLE CAUSE: A bomb, placed on board by a Sikh terrorist, caused an explosion, powerful enough to cause an inflight break-up. Source: Aircraft hijackings and other criminal acts against civil aviation : statistical and narrative reports / FAA; Aviation disasters / D. Gero (p. 182-183); Air Disasters / S. Stewart; Flight International 1.11.86 + 18.10.86

15) 12.08.85 (18.56) Boeing 747-SR46

JA-8119 (20783/230) Japan Air Lines - JAL 520 fatalities / 524 occupants +
Location: Tokyo; nr (Japan) Nature: Scheduled Passenger Phase: Climb from: Tokyo-Haneda IAP to: Osaka IAP Flightnr.: JL123 JAL Flight 123 took off from Tokyo-Haneda at 18.12h for a flight to Osaka. At 18.24h, while climbing through 23900ft at a speed of 300kts, an unusual vibration occurred. An impact force raised the nose of the aircraft and control problems were experienced. Two minutes later hydraulic pressure had dropped and ailerons, elevators and yaw damper became inoperative, followed by dutch roll and plughoid oscillations (unusual movement in which altitude and speed change significantly in a 20-100sec. cycle without change of angle of attack). The aircraft started to descend to 6600ft while the crew tried to control the aircraft by using engine thrust. Upon reaching 6600ft the airspeed had dropped to 108kts. The aircraft then climbed with a 39deg. angle of attack to a maximum of approx. 13400ft and started to descend again. JA123 finally brushed against a tree covered ridge, continued and struck another ridge, bursting into flames. PROBABLE CAUSE: "Deterioration of flight characteristics and loss of primary flight controls due to rupture of the aft pressure bulkhead with subsequent ruptures of the tail, vertical fin and hydraulic flight control systems. The reason for the aft pressure bulkhead rupture was that its strength was reduced by the fatigue cracks propagating in the spliced portion of the bulkhead's webs. The initiation and propagation of the fatigue cracks are attributable to the improper repairs of the bulkhead, conducted in 1978, and since the fatigue cracks were not found in the later maintenance inspections, this contributed to the accident." Source:

16) 02.12.85 () Boeing 747-228B

F-GCBC (22427/485) Air France
0 fatalities / 273 occupants +
Location: Rio de Janeiro (Brazil) Nature: Scheduled Passenger Phase: Landing

The aircraft veered off the runway on landing, crossed a ditch and collided with a concrete ramp. It appeared that the no.1 engine throttle cable had broken, making it impossible for the flightcrew to control engine power. The engine had accelerated to an unusually high level of (forward) thrust (above take-off power).

17) 28.11.87 (00:07 UTC) Boeing 747-244B ZS-SAS (22171/488) South African Airways - SAA 159 fatalities / 159 occupants +

Location: Indian Ocean () Nature: Scheduled Passenger Phase: Descent from: Taipei-Chang Kai Shek IAP to: Flightnr.: SA295 South African flight 295 took off from Taipei at 14.23, carrying 159 occupants and 6 pallets of cargo in the main deck cargo hold. At 23.49h the crew reported Mauritius Approach control they had a fire on board. An emergency descent to FL140 was carried out. Mauritius ATC cleared the aircraft to FL50, followed by a approach clearance. The captain's response was the last radio contact with SA295. It appeared that a fire had started in the cargo pallet at position PR. The aircraft had somehow lost control, broke up and crashed into the Ocean. PROBABLE CAUSE: Fire of an unknown origin had possibly: 1) incapacitated the crew; 2) caused disorientation of the crew due to thick smoke; 3) caused crew distraction; 4) weakened the aircraft structure, causing an inflight break-up.; 5) burned through several control cables; 6) caused loss of control due to deformation of the aircraft fuselage. Source:

18) 21.12.88 (19.03) Boeing 747-121A

N739PA (19646/15) Pan American World Airways 259 fatalities / 259 occupants + 11

Location: Lockerbie (UK) Nature: Scheduled Passenger Phase: Cruise from: London-Heathrow APT to: New York-John F. Kennedy IAP Flightnr.: PA103 Flight PA103 departed London-Heathrow Runway 27R for New York at 18.25. The aircraft levelled off at FL310 31 minutes later. At 19.03 Shanwick Oceanic Control transmitted an oceanic clearance. At that time an explosion occurred in the aircraft's forward cargo hold at position 4L. The explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. Major cracks continued to propagate from the large hole while containers and items of cargo ejected through the hole, striking the empennage, left- and right tailplane. The forward fuselage and flight deck area separated when the aircraft was in a nose down and left roll attitude, peeling away to the right at Station 800. The nose section then knocked the No.3 engine off its pylon. The remaining aircraft disintegrated while it was descending nearly vertically from 19000ft to 9000ft. A section of cabin floor and baggage hold (from approx. Station 1241-1920) fell onto housing at Rosebank Terrace, Lockerbie. The main wing structure struck the ground with a high yaw angle at Sherwood Crescent, Lockerbie causing a massive fire. The Semtex bomb which caused the explosion had probably been hidden in a radio cassette player and was transferred to PA103 from a Pan Am Boeing 727 flight, arriving from Frankfurt. The Popular Front for the Liberation of Palestine General Command (PFLP-GC) was probably the organization responsible for the bombing. PROBABLE CAUSE: "The in-flight disintegration of the aircraft was caused by the detonation of an improvised explosive device located in a baggage container positioned on the left side of the forward cargo hold at aircraft station 700." (Accident Report 2/90) Source: ICAO Circular 260-AN/154 (133-188); ASW 12.4.93(3); AW&ST 2.1.89 (28-32)

19) 19.02.89 (06.36) Boeing 747-249F

N807FT (21828/408) Flying Tiger Line

4 fatalities / 4 occupants +

Location: Kuala Lumpur; 7,5 mls (Malaysia) Nature: Freight Phase: Final Approach from: to: Kuala Lumpur-Subang IAP Flightnr.: FT66 The Boeing crashed into a wooded hillside, while on an NDB approach to Runway 33. The aircraft had descended 1800ft below minimum altitude and collided with a hill at 600ft MSL. PROBABLE CAUSE: Non-standard phraseology was used by

Kuala Lumpur ATC, causing the the crew to misinterpret the instructions.
Source: ICAO Adrep Summary; AW&ST 27.02.89 (24); FI 17- 12.01.90 (44)

20) 07.05.90 () Boeing 747-237B

VT-EBO (20558/188) Air India

0 fatalities / 215 occupants +

Location: Delhi (India) Nature: Scheduled Passenger Phase: Landing from: London-Heathrow APT to: Delhi-Indira Gandhi IAP Flightnr.: AI132 The Boeing 747 touched down at Delhi after a flight from London. On application of reverse thrust, a failure of the no.1 engine pylon to wing attachment caused this engine to tilt nose down. Hot exhaust gases caused a fire on the left wing. The aircraft was damaged beyond repair. PROBABLE CAUSE: "The accident was caused due to the migration of the improperly installed diagonal-brace aft fuse-pin of the No.1 engine from its fitting which substantially reduced the load carrying capability of the engine fittings resulting in failure of the upper-link forward fuse pin due to excessive loads on account of probably improper landing leading to a partial separation of engine and fire." Source: NTSB/SIR-94/02 (p. 16)

21) 18.02.91 () Boeing 747-136

G-AWND (19764/107) British Airways

0 fatalities / 0 occupants +

Location: Kuwait City IAP (Kuwait) Nature: - Phase: Ground from: - to: - Flight nr.: - The aircraft was at Kuwait Airport during the Iraqi invasion of August 2, 1990 and blown up by Iraqi forces when allied forces intervened.

22) 29.12.91 (ca 15.05) Boeing 747-2R7F B- 198 (22390/482) China Airlines

5 fatalities / 5 occupants +

Location: Wanli; nr (Taiwan) Nature: Freight Phase: Climb from: Taipei-Chang Kai Shek IAP to: Anchorage IAP Flightnr.: CI358 The aircraft was climbing through 5200ft when the no.3 engine separated from the wing. The engine struck the no.4 engine, which separated also. Control was lost and the aircraft crashed into a hillside at 700ft. The aircraft had accumulated 45868 hours and 9094 cycles. PROBABLE CAUSE: Initial findings suggest a failure of both no.3 engine inboard midspar fittings, partly in fatigue partly ductile. Source: S152; Aircraft Accident Report 92-11 El Al Flight 1862 ... / Netherlands Aviation Safety Board (p.32); AW&ST 6.1.92 (23); fi 8-14.1.92 (11)

23) 04.10.92 (17.35 UTC) Boeing 747-258F 4X-AXG (21737/362) El Al

4 fatalities / 4 occupants + 47

Location: Amsterdam (Netherlands) Nature: Freight Phase: Climb from: Amsterdam-Schiphol APT to: Tel Aviv-Ben Gurion Flightnr.: LY1862 PROBABLE CAUSE: "The design and certification of the B747 pylon was found to be inadequate to provide the required level of safety. Furthermore the system to ensure structural integrity by inspection failed. This ultimately caused - probably initiated by fatigue in the inboard midspar fuse-pin - the no.3 pylon and engine to separate from the wing in such a way that the no.4 pylon and engine were torn off, part of the leading edge of the wing was damaged and the use of several systems was lost or limited. This subsequently left the flight crew with very limited control of the airplane. Because of the marginal controllability a safe landing became highly improbable, if not virtually impossible." Source: Aircraft Accident Report 92-11 El Al Flight 1862 Boeing 747-258F 4X-AXG Bijlmermeer, Amsterdam October 4, 1992 / Netherlands Aviation Safety Board; NTSB Safety Recommendations A-92-117

24) 04.11.93 () Boeing 747-409

B- 165 (24313/966) China Airlines

0 fatalities / 396 occupants +

Location: Hon Kong-Kai Tak APT (Hong Kong) Nature: Scheduled Passenger Phase: Landing from: to: Hon Kong-Kai Tak APT Flightnr.: CI605 The aircraft skidded off the wet runway and ended up in shallow water. The flight landed with heavy crosswinds, caused by tropical storm Ira. Source: ASW 8.11.93(4) + ASW 13.12.93(6) + ASW 28.3.94(3); Air Letter No. 13,186 - 20.2.95 (1)

25) 20.12.95 (11.36 EST) Boeing 747-136 N605FF (20271/172) Tower Air
0 fatalities / 468 occupants +

Location: New York-John F. Kennedy IAP (USA) Nature: Scheduled Passenger Phase: Take-off from: New York-John F. Kennedy IAP, NY to: Miami IAP Flightnr.: FF41 Flight 41, bound for Miami was pushed back from the gate at 10.36h. At 11.00h deicing procedures were started at 11.00h, using both Type I and Type II fluids. The crew received clearance for Runway 4L at 11.16h and started to taxi slowly towards the assigned runway. The aircraft was stopped on the taxiway to clear the engines of any ice by increasing power to 45% N1 for 10 seconds. The aircraft continued and the flight was cleared to taxi in position and hold at 11.32h and got take-off clearance at 11.36h. The take-off was normal, until shortly before 80kts. The aircraft started to move to the left; corrections by the crew were ineffective. The captain then aborted the takeoff by retarding powerlevers to idle and by applying maximum braking. He didn't use reverse thrust, because of the slow speed, long runway and the possibility that it could worsen directional control. At 2100ft past the threshold, the 747 departed the left side of the runway. The aircraft finally struck a transformer, causing the no,4 engine to separate. The Boeing came to rest at 4800ft past the threshold and 600ft to the left of the runway centerline with the nosegear collapsed. PROBABLE CAUSE" The captain's failure to reject the takeoff in a timely manner when excessive nosewheel steering tiller inputs resulted in a loss of directional control on a slippery runway. Inadequate Boeing 747 slippery runway operating procedures developed by Tower Air, Inc., and the Boeing Commercial Airplane Group and the inadequate fidelity of Boeing 747 flight training simulators for slippery runway operations contributed to the cause of this accident. The captain's reapplication of forward thrust before the airplane departed the left side of the runway contributed to the severity of the runway excursion and damage to the airplane." (NTSB)

Source: AW&ST 1.1.96(31); Knipselkrant Luchtvaart 52-1995; S201(50); ASW 29.01.96(6) + 05.02.96(7) + 26.02.96(7) + 4.11.96 (8); NTSB Safety Recommendations A-96-45 through -47

26) 17.07.96 (20.31 EDT) Boeing 747-131 N93119 (20083/153) Trans World Airlines - TWA
230 fatalities / 230 occupants +

Location: Long Island, off (USA) Nature: Scheduled Passenger Phase: Climb from: New York-John F. Kennedy IAP, NY to: Paris-Charles de Gaulle Flightnr.: TW800

27) 12.11.96 (18.40) Boeing 747-168B

HZ-AIH (22748/555) Saudia

312 fatalities / 312 occupants + 37

Location: Charki Dadri; 3mls (India) Nature: Scheduled Passenger Phase: Climb from: Delhi-Indira Gandhi IAP to: Dhahran IAP Flightnr.: SV763 Air Kazakhstan Flight 1907 had taken off from Chimkent for a flight to New Delhi and was inbound to Delhi on Airway G452, descending to FL150. Saudia Flight 763 had taken off from New Delhi at 18.32h for a scheduled flight to Dhahran and Jeddah. The aircraft followed the Parvi SID and climbed to FL140. Apparently the Kazakh aircraft had descended below its assigned altitude and was flying at 14500ft when the crew were told there was a Saudi Boeing 747 8 miles away at FL140. Thirteen seconds later the Ilyushin had descended another 310ft. Shortly afterwards both aircraft collided, plummeted down in flames and crashed in an arid farming area. Source: AW&ST 18.11.96 (34-36); IHT 6.5.97 Pilot error focus of India Collision investigation - Nov. 14, 1996 India buries, cremates victims of air disaster - Nov. 14, 1996

28) 05.08.97 (01.50) Boeing 747-3B5

HL7468 (22487/605) Korean Air

223 fatalities / 254 occupants +

Location: Guam-Agana IAP; nr (USA) Nature: Scheduled Passenger Phase: Final Approach from:

Seoul-Kimpo IAP to: Flightnr.: KE801

**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

Appendix B: Avianca Accident
(Unofficial narrative)

I. Introduction

On November 27, 1989, Avianca Airlines Flight 203, originating from Bogota, Colombia, exploded shortly after take-off, killing the 107 persons on board including two Americans. SSA Richard Hahn was assigned to this case as part of a team of representatives from the United States. Hahn collected evidence at the crime scene, examined evidence, and prepared a final report. Dandeny Munoz-Mascara (Munoz) was indicted for causing the explosion and in 1994 was tried twice in the Eastern District of New York. The first trial resulted in a mistrial; he was convicted in the second trial. Hahn testified as an explosives expert in both trials.

Whitehurst alleges that in the trials Hahn, among other things, fabricated evidence, committed perjury, and testified outside his area of expertise. Whitehurst's principal allegations concern Hahn's testimony about (1) the type of explosive that caused the crash, (2) Whitehurst's scientific results, and (3) the fire and secondary explosion that followed the initial blast.

To investigate Whitehurst's claims, we reviewed the pertinent Laboratory reports and, where available, the underlying work papers and test results. We reviewed transcripts of the testimony of Hahn and the closing arguments made by the prosecutor in both trials. We also questioned agents Hahn and Whitehurst and their former unit chiefs, J. Christopher Ronay and James Corby. Finally, we also interviewed others involved in the case, including Edward Bender, James Kearney, Donald Thompson, Dwight Dennett, former Assistant United States Attorneys (AUSAs) Cheryl Pollak and Beth Wilkinson (who jointly tried the Munoz case twice), and DEA agent Sam Trotman.

We conclude that Hahn did not commit perjury or fabricate evidence. We further conclude, however, that Hahn gave testimony that was, in part, either scientifically unsound or beyond his expertise. We also conclude that Kearney erred when he failed to resolve a dispute between Hahn and Whitehurst; the result was that Hahn gave incomplete testimony regarding Whitehurst's scientific results. Finally, we conclude that Whitehurst sent a scientifically flawed memorandum to the prosecutor during the first trial and committed other errors in the case.

The following section (Section II) summarizes the factual background to the allegations. Section III analyzes the issues relating to Hahn's testimony (Section A) and Whitehurst's conduct (Section B). We state our conclusions in Section IV.

II. Factual Background

A. The Crime Scene

On November 29, 1989, Hahn arrived in Colombia to investigate the crash. While there, he met with and discussed the aircraft explosion with experts from the Federal Aviation Administration

(FAA) and the National Transportation Safety Board (NTSB). He and other experts in various fields examined the crime scene, collected evidence, attempted to reconstruct the aircraft, and formed theories as to what happened.

After days of investigation, Hahn and the FAA representatives concluded as follows: A small explosive device functioned on the aircraft beneath a seat over the wing. This explosion breached certain portions of the aircraft and caused a fire and a second explosion described as a fuel-air explosion, which blew the aircraft apart and sent it to the ground in pieces.

On December 6, 1989, while Hahn was still in Colombia investigating the Avianca crash, a Colombian government building (the DAS Building) was bombed. Later that day Hahn went to the scene of the DAS explosion to offer his assistance. He examined the damage there and took soil samples in which no explosives residues were found.

B. The Laboratory Analysis

Hahn sent samples of evidence from the Avianca crime scene to the FBI Laboratory. Once the samples arrived, an EU technician catalogued the evidence and sent it to various units in the Laboratory for examination. Whitehurst, as an examiner in the MAU, was asked to examine various items for explosives residues. Edward Bender, the technician then assigned to Whitehurst, received and analyzed this evidence. As was customary in the Laboratory, Bender ran the instrumental analysis and reported the results to Whitehurst. Whitehurst's role as an examiner was to review and draw conclusions from the data provided by the technician.

In January 1990 Whitehurst identified RDX and PETN high explosives on a specimen from a portion of the aircraft. He wrote a report (dictation), which was approved by MAU Chief James Corby and was sent to Hahn who included it verbatim in one of his two reports. In his other report Hahn noted that a portion of the aircraft skin bore pitting and cratering unique to high explosives. Hahn concluded that an explosive device with a relatively small amount of high explosives functioned on board the aircraft, causing a breach of the fuselage and other parts of the aircraft, a fire, and a fuel-air explosion that caused the aircraft to break apart.

C. The Confessor

In the spring of 1994, on the eve of the first Munoz trial, the Attorney General of Colombia wrote a letter to the District Court Judge in the case and stated that the wrong person was charged in the Avianca case and that the responsible person was in custody in Colombia and had confessed to the crime. In interviews by an ATF agent in Colombia, the Confessor stated, among other things, that he was responsible for making the bomb that destroyed Avianca Flight 203 and that the explosive consisted of 5 kilograms of an ammonium based gelatin dynamite. The Confessor claimed that this dynamite was A the same explosive used at the DAS Building.

The Munoz prosecutor sought Hahn's advice regarding this development. According to a memorandum Hahn wrote in 1995, he advised the prosecutor [in 1994] that neither was the damage to the aircraft consistent with dynamite, based on the pitting and cratering that was present on the fuselage, nor was the damage consistent with the functioning of a single dynamite device of five kilos in size. Hahn added that his opinion was A supported by the finding of residues RDX and PETN and the lack of residues consistent with a dynamite.

On June 4, 1994, Hahn telephoned Whitehurst to tell him that he (Whitehurst) might be called as a witness to rebut the claims of the Confessor, which Hahn described. According to Whitehurst, Hahn asked whether Whitehurst could discredit the Confessor's story based on the residue

analysis. According to Hahn, he asked Whitehurst, A[C]an you say, from your material analysis, whether or not this might have been an ammonia gel dynamite or not.

During the June 4, 1994, conversation, Hahn told Whitehurst that Hahn believed the pitting and cratering on the evidence was indicative of an explosive with a VOD of 20,000 feet per second. Whitehurst responded that there are ammonia-gel dynamites capable of detonation velocities of approximately 20,000 feet per second and that therefore the damage may have been possible from such a dynamite. Hahn dismissed Whitehurst's views because Whitehurst was not at the crime scene or aircraft reconstruction and because explosives damage assessment is outside Whitehurst's expertise. Hahn did not ask Whitehurst to prepare any documents regarding his analysis of the Confessor's statement. On June 6th Hahn faxed Whitehurst a copy of one of the Confessor's statements.

D. The Whitehurst Memorandum

On June 7, 1994, Whitehurst prepared a memorandum to Corby (the Whitehurst Memorandum) relating to whether the FBI could scientifically disprove the Confessor's story. The following day Whitehurst delivered to Corby the memorandum with technical papers that Whitehurst claimed supported his views. Whitehurst stated in the memorandum that he could not disprove the use of an ammonium gel dynamite and that in fact the data is consistent with the use of an ammonium nitrate based high explosive. The memorandum asserted that the pitting and cratering did not rule out the use of a gelatin dynamite, citing the attached literature. Whitehurst also raised questions concerning possible contamination that would affect the significance of his previous findings of PETN and RDX.

Corby reviewed the memorandum overnight, and on June 9, 1994, according to Whitehurst, Corby told him to quickly provide Whitehurst's assessment to the prosecutor. Corby stated that he did not authorize Whitehurst to send the memorandum itself directly to the prosecutor, only to provide the information in the memorandum to the prosecutor. On June 9, 1994, Whitehurst gave the memorandum to an agent on the case (Dwight Dennett) to give to the prosecutor. Dennett delivered the document as promised. Whitehurst did not send a copy of the memorandum to Hahn or discuss this memorandum with him prior to sending it to the prosecutor.

On June 14, 1994, Whitehurst received a note from Corby stating that AUSA Pollak wanted to talk to him. Whitehurst called Pollak, who was angry. They discussed the memorandum. According to Whitehurst, Pollak explained the concept of Brady material and told Whitehurst that now she would have to turn the information over to the defense. At about the same time, Pollak also told Hahn that she would have to disclose the memorandum to the defense under Brady. Although Hahn later assumed the Whitehurst Memorandum was disclosed to the defense, it is unclear whether in fact disclosure was made. The prosecutors did not contact Whitehurst further regarding this case.

E. The Trials

Hahn testified in the first Munoz trial on June 7, 1994. This was two days before Whitehurst gave his memorandum to Dennett, and thus Hahn did not have the memorandum when he testified. Among other things, Hahn testified to his opinion as to how the initial and secondary explosions occurred on the aircraft and related the conclusions regarding RDX and PETN as set forth in Whitehurst's dictation. Hahn also gave testimony that tended to contradict the Confessor's story by asserting that the damage to the aircraft indicated the use of a fast-moving explosive like RDX or PETN while the damage to the DAS Building indicated a slower-moving explosive like dynamite.

On June 14, 1994, Hahn received a copy of the Whitehurst Memorandum from Pollak. He then sent a copy to his former unit chief, J. Christopher Ronay, and discussed the matter with him. Between the two trials, SAS Chief James Kearney, MAU Chief Corby, and Ronay addressed the issues raised by Whitehurst's Memorandum but made no communication to Hahn regarding any resolution of the controversy. Hahn, therefore, proceeded to the second trial with no guidance from management about how to testify in light of the views expressed in the Whitehurst Memorandum.

On November 22, 1994, during the second trial, Hahn repeated essentially the same testimony he gave in the first trial. No mention was made of any of the opinions discussed in the Whitehurst Memorandum.

III. Analysis

A. Hahn's Testimony

1. Contradiction of Confessor, Pitting and Cratering

In both trials Hahn opined that the pitting and cratering on the fuselage of the aircraft was caused by an extremely or Avery high explosive but that the DAS Building was damaged by a slower-moving explosive such as dynamite. This testimony contradicted the Confessor's story that the same explosive--a dynamite--was used at the DAS Building and on the aircraft. We conclude that Hahn's opinions correlating the pitting and cratering to a high velocity explosive were unsound and not justified by his experience or by the scientific literature. Although a high velocity explosive may have been used on the aircraft, Hahn's opinions at the trials regarding pitting and cratering were flawed.

a. Trial Testimony

In the first trial, Hahn testified that an extremely high explosive caused the pitting and cratering on the aircraft, that RDX and PETN are explosives in that category, that no dynamite could have caused that damage, and that the damage at the DAS Building was indicative of a heaving explosive such as dynamite and not a brisant explosive like RDX or PETN. Hahn further testified that by extremely high explosive he meant the ones that do travel at 22, 24 thousand feet per second. Hahn was certain that this testimony contrasting dynamite with RDX and PETN was elicited to anticipate and contradict the Confessor's story should it be introduced by the defense. A defense based on the Confessor, however, was not interposed in either trial.

In the second trial Hahn testified that the pitting and cratering on the fuselage was caused by a very high explosive here functioning in the area of 20,000 feet per second. Regarding the damage at the DAS Building, he testified:

It indicated to me that again the explosive that was used here, unlike the explosive device or an explosive that would cause pitting and cratering, this was a much slower moving explosive. This was going to be like a dynamite or ammonia-base type nitrate explosive that would have a long period heaving effect, if you will.

b. Validity of Hahn's Correlation of the Pitting to a VOD Range

In the first trial, Hahn testified that no dynamite could have caused the pitting and cratering on the

aircraft. This testimony was clearly erroneous even under Hahn's own theories, since Hahn firmly maintains that the pitting was caused by an explosive with a VOD of about 20,000 feet per second and he testified at the first trial and the OIG interviews that some dynamites have a VOD in that range.

Taken literally, Hahn's testimony in the second trial indicated that he believed the phenomenon of pitting and cratering can only occur with a Avery high explosive --that is, an explosive with a VOD of about 20,000 feet per second or more. This is implied from his testimony that the damage at the DAS Building was indicative of an explosive such as a dynamite rather than an explosive that would cause pitting and cratering. Hahn told us in his first interview that at the time of the Munoz trials he had only experienced pitting and cratering with explosives having a VOD of at least 20,000 feet per second and believed that pitting and cratering would only occur with such explosives. Hahn's experience, however, was, at best, incomplete. In fact, pitting and cratering can be achieved with some high explosives with a VOD as low as 10,000 feet per second. Most dynamites have a VOD in excess of 10,000 feet per second.

In a letter after his first OIG interview and in a second interview, Hahn insisted that his testimony should not be taken literally. He maintained that when he said the explosive at the DAS Building was not the type of explosive that would cause pitting and cratering, he meant it was not the type of explosive that would cause the distinctive pitting and cratering on the Avianca aircraft. The pits on the aircraft had diameters of about one-eighth to one-quarter inch. By contrast, the pitting and cratering discussed in the articles attached to the Whitehurst Memorandum contained much smaller pits (.1 to .5 millimeters). To Hahn the size of the pits on the Avianca aircraft indicated a VOD of about 20,000 feet per second or more. Hahn insisted that it was this type of pitting and cratering (A the large pits) that he was referring to in his trial testimony.

Hahn believed that large pits, as in the Avianca case, are indicative of a VOD of about 20,000 feet per second or more because he had never seen pitting of that size or anything closely resembling that except with explosives in the range of 20,000 ft/second detonation velocity. Hahn has seen such pitting in his tests of shaped charges at the FBI range. In these tests Hahn used explosives with a VOD of at least 20,000 feet per second. Hahn theorized that the pitting on the Avianca aircraft was caused by jetting resulting from a deformation on the explosive's surface that was, in effect, a small shaped charge. See also Hahn OIG Interview: AI speculated far enough to say, there had to be some imperfection in this explosive charge to cause this shape, to form this jet.

Hahn admitted, however, that in his tests with shaped charges at the range he had never seen such pitting at all except when he was trying to deliberately achieve that effect with a shaped charge that was lined (e.g., with an old vehicle headlight) and that he had never experimented with shaped explosives with a VOD less than 20,000 feet per second. Based on this experience, therefore, Hahn was unqualified to say whether it was the shaping, the fragmentation from the lining, or the high velocity, or some combination of these elements, that was necessary to produce the large pits.

Moreover, the pitting here was found on aircraft aluminum, and Hahn had no experience using aircraft aluminum as a target material with any type of explosive. Hahn acknowledged that pitting would occur more readily on aircraft aluminum than on steel, which Hahn used in his tests.

Hahn assumed that the perpetrators of the Avianca blast did not take the time to create an intentionally shaped charge. Hahn's tests at the FBI range, in which he obtained pitting similar to Avianca's, involved lined, intentionally shaped charges and targets of steel, which had little connection to the scenario he posited in the Avianca case--an explosive not intentionally shaped with a target of aircraft aluminum.

Hahn theorized that the jetting that caused the large pits on the aircraft came from random imperfections at the surface of the explosive. Hahn acknowledged, however, that he has no experience, documentation, or anything that validates the proposition that such pits can be created from accidental imperfections on the explosive.

Additionally, Hahn admitted at one point in the OIG interviews that the pitting and cratering in this case is merely consistent with an explosive with a VOD of at least 20,000 feet per second. He stated that, because we don't have the experimental data, he cannot exclu[de] other explosives.

Accordingly, for all these reasons, we conclude that Hahn's experience was inadequate to support his opinion that the large pits found on the aircraft aluminum in this case were necessarily caused by an extremely or Avery high explosive with a VOD of at least 20,000 feet per second.

Hahn's correlation of the pitting to a VOD range was not based on his experience but was a speculative extrapolation from his experience. This speculation was based on Hahn's understanding of the science of pitting and cratering (his jetting theory). Hahn admitted, however, that the science of pitting and cratering is beyond his expertise: I'm not qualified to talk to you about exactly how this process functions. I'm not even sure that the scientific community knows exactly what goes on here, to be honest with you. Hahn was qualified to render opinions based only on his experience, which did not justify his attempt to correlate the pitting with the VOD of the explosive.

Hahn asserted that he relied on his jetting theory because AI don't know how else you would get that damage. That Hahn could conceive of no other theory, however, did not make his jetting theory valid.

Finally, Hahn's recent involvement in the Oklahoma City case has broadened his experience. The pitting in that case is similar in size to the pitting in the Avianca case, although the VOD of the explosive in Oklahoma City, according to Hahn, is significantly below 20,000 feet per second. Given the Oklahoma City case, Hahn acknowledged that big pits can be obtained from an explosive with a VOD substantially less than 20,000 feet per second. Based on the Oklahoma City case and our own experience, we conclude that there is no scientific basis for correlating large pits, as in the Avianca and Oklahoma City cases, with a VOD of about 20,000 feet per second or more.

c. Other Theories in Support of Hahn's VOD Opinion

Hahn also told us that his opinion that the explosive had a VOD of at least 20,000 feet per second rested on two factors in addition to the pitting and cratering: (1) the shattering of an I-beam on the aircraft showing that the explosive was very brisant and (2) the short amount of time the gas jet would have had to cause the pitting before the explosive shock wave and the depressurization of the cabin pushed the fuselage away. This explanation is problematic for three reasons. First, Hahn's VOD opinions at the trials only relied on the pitting and cratering. Second, the evidence that the I-beam in fact was shattered by the explosive is weak. All that one can say with certainty is that a portion of the I-beam, like many other portions of the aircraft, was missing. Hahn made no scientific comparison between (1) the ends of the I-beam that were adjacent to the missing piece and (2) the ends of other items adjacent to missing pieces, to determine whether the breakage of the I-beam was necessarily from a brisant explosive. Further, in the opinion of Walter Korsgaard, the FAA expert who investigated the Avianca crash, the wing box that contained the I-beam was violated after the second (fuel-air) explosion. Third, regardless of the VOD of the explosive, a gas jet will precede the shock wave and hit the target before the shock wave pushes it away. Hahn made no calculations of the difference in speed between a jet from an explosive with a VOD of 20,000 feet per second and a jet from an explosive with a VOD of, say, 16,000 feet per second.

Needless to say, jets from either explosive would travel extraordinarily fast. Hahn has no scientific basis for concluding that the depressurization of the cabin would have pushed the fuselage away before it could have been hit by a jet from an explosive with a VOD below 20,000 feet per second.

On January 8, 1997, an attorney representing Hahn submitted a letter arguing, among other things, that, quite apart from the pitting and cratering, Hahn's VOD opinion was reasonable in light of (1) the shattering of the I-beam and (2) the detection of residue of RDX and PETN. The letter asserts that these two factors, taken together, alone establish the reasonableness of Agent Hahn's conclusion. (Emphasis in original). Again, this justification is not the one Hahn used in his trial testimony, in which he asserted that the pitting established the explosive's VOD. In any event, as discussed in the preceding paragraph, the evidence that the I-beam was shattered in such a way as to show high brisance is weak. As to the second factor, if the explosive device on the aircraft used RDX and PETN as the explosive main charge, then by definition the main charge would have had a VOD in excess of 20,000 feet per second since the VODs of RDX, PETN, and Semtex (which combines RDX and PETN) exceed 23,900 feet per second. The residue evidence does indicate that the main charge may have consisted of RDX and PETN and that therefore the VOD of the main charge may have exceeded 23,900 feet per second. Had Hahn so testified, his testimony would have been reasonable, but he testified to something else. The problem with Hahn's testimony was that he correlated the pitting to a particular VOD range. That testimony was scientifically unsound and not justified by Hahn's experience, regardless of what the residue evidence may have shown.

d. Hahn's Rejection of the Whitehurst Literature

On June 14, 1994--a few days after his testimony in the first trial and 5 months before his testimony in the second trial--Hahn received the Whitehurst Memorandum with its attached scientific literature. One of the attached articles indicated that pitting and cratering could be achieved on aircraft aluminum with a 40% Forcrite gelatin dynamite. Although Hahn assumed in 1994 that this dynamite had a VOD of 20,000 feet per second, in fact its VOD is about 13,800 feet per second.

Hahn told us that he ignored the literature when he testified in the second trial, because the pitting depicted in the literature (pits with a diameter of .1 to .5 millimeters) was vastly different in dimension from the pitting in the Avianca case (pits with a diameter of 1/8 to 1/4 inch). Hahn stated in his interview that A[u]ntil such time as I saw Mr. Whitehurst's paper, I never paid attention to, looked for, [or] was even aware of this sort of microscopic pitting and cratering that that paper refers to.

The literature also discussed how pitting and cratering is caused. One article (by H. P. Tardif and another author) stated:

This phenomenon can be produced by two separate mechanisms. The first is due to the shaped charge effect caused by tiny imperfections at the surface of the charge. These imperfections, such as holes and cavities, collapse to form extremely high velocity jets of gases which impinge on the surface to form small crater-like pits. The second appears to be caused by the high velocity impact of small amounts of unconsumed explosive with a nearby surface or by friable extraneous material placed between the charge and the nearby surface.

A second article (by D. G. Higgs and T. S. Hayes) stated: AIt is thought that the pits are caused by the impingement of high velocity particles of partially combusted explosive and/or fused extraneous matter encountered between the explosive charge and the witness' material.

The Tardif and Higgs explanations differed from Hahn's jetting theory in two respects. First, Hahn believed that pitting was derived from gas jets. Both articles, however, provide another mechanism for pitting--namely, the impingement of particles of unconsumed explosive or extraneous matter placed between the explosive and the target. Second, the Tardif article does include as one mechanism Hahn's theory that pits can be caused by jets formed from imperfections at the surface of the explosive. But Tardif states that these pits will be small, presumably within the size range discussed in the article (.1 to .5 millimeters). The Tardif article thus at least raises the question whether Hahn's jetting theory can account for the large pits on the Avianca aircraft.

After Hahn received the Whitehurst memorandum and the attached scientific literature, he made no inquiries before the second trial concerning the soundness of his theories regarding pitting and cratering. Because Hahn was unfamiliar with microscopic pitting and had no experience with pitting on aircraft aluminum and because the articles raised questions concerning the validity of his jetting theory, we conclude that Hahn erred when he failed to look into these matters before he testified in the second trial.

2. Hahn's Testimony About the Results of Whitehurst's Examination

Whitehurst contends that in both trials Hahn gave inappropriate testimony regarding the findings of RDX and PETN, because Hahn failed to mention the conclusions set forth in the Whitehurst Memorandum. We conclude that Hahn's testimony in the first trial was unobjectionable but that his testimony in the second trial was incomplete. Further, we conclude that SAS Chief James Kearney contributed to Hahn's incomplete testimony by not properly resolving the issues raised by the Whitehurst Memorandum. As discussed in Section B, infra, however, the Whitehurst Memorandum was a deeply flawed document. Accordingly, the impact of Hahn's failure to mention the opinions in the document may have been insignificant.

a. Background

In 1990 Whitehurst submitted AE dictation in which he identified the presence of RDX and PETN high explosive[s] on a specimen consisting of a piece of the rubber fuel bladder Hahn had cut from the Avianca wreckage in Colombia. The dictation contained no other findings on any specimen. The instrumental analyses upon which Whitehurst based his conclusions were performed by a technician, Edward Bender.

On June 8, 1994, the Whitehurst Memorandum was submitted to Corby. In the memorandum, Whitehurst reviewed this matter and offered opinions that supplemented or questioned his 1990 dictation. Whitehurst stated: AIt is my opinion at this time that the data we acquired from analysis of the evidence provided to us in this matter does not disprove the use of an ammonium nitrate based high explosive and in fact is consistent with but not proof of the use of such an explosive. Regarding his 1990 chemical analysis that detected PETN and RDX, Whitehurst stated that A[a] number of questions [about possible contamination] need to be answered before we can determine the significance of that data. He then listed a series of questions concerning possible contamination at the crime scene, during transportation of the evidence, and during the processing of the evidence at the Laboratory. He further opined that A[t]he upshot of all of this is that the data we have at this time cannot be used to successfully disprove the statement that a gelatin dynamite was used in this bombing.

On June 14, 1994, a week after he testified in the first trial, Hahn received the Whitehurst Memorandum. He discussed the memorandum with EU Chief Ronay and sent Ronay a copy of the

memorandum on June 14, 1994. On June 16, 1994, Ronay sent a memorandum to SAS Chief Kearney regarding the Whitehurst Memorandum, which he attached. On June 22, 1994, Hahn also sent Kearney a memorandum. Shortly after receiving Ronay's memorandum, Kearney sent a list of questions to Corby about the events surrounding the Whitehurst Memorandum and its dissemination to Pollak. Corby responded to Kearney's questions in writing on July 6, 1994. Corby supported many of Whitehurst's opinions.

Kearney told us he thought both Hahn and Whitehurst should have testified at the trials. However, neither Kearney, Ronay, nor any other supervisor advised Hahn on how he should deal with the Whitehurst Memorandum in his testimony at the second trial.

Hahn regarded the Whitehurst Memorandum as a rejection of his [Whitehurst's] own scientific findings. Hahn stated, "In this case, Mr. Whitehurst has, in writing, offered an opinion contrary to his own scientific findings. Nevertheless, on November 22, 1994, Hahn testified in the second Munoz trial that in 1990 he submitted pieces of the aircraft and swabbings to the Materials Analysis Unit of the F.B.I. laboratory to try -- who specialize in looking for explosives residue to try to determine what explosive was used here.

Q. What were the results of those tests?

A. The results were although they found no residue that they could identify here on this piece, or any other piece, except a piece of the fuel bladder, and on that piece of fuel bladder taken from the area right immediately underneath the blast, they found residue of two explosives, Research Development Explosive, RDX, which is again a very fast brisant explosive; and PETN, or Penta-erithrit[o]l tetranitrate. . . .

In his testimony Hahn made no mention of anything in the Whitehurst Memorandum.

Hahn maintains that he properly ignored the Whitehurst Memorandum in his testimony for the following reasons:

What he says in the letter [referring to the Whitehurst Memorandum] is not based on any sort of analysis. What he says in the letter is based on speculation, it's not the results of his material analysis.

I mean, Fred does nothing in that letter [but] speculate as to what could have been or what might have been or what may have occurred. His scientific analysis, his instrumental analysis that he conducts, still remains that the results were PETN and RDX.

Furthermore, I spoke to Bender, who actually conducted it, who, again, was completely comfortable with those results, felt they could be relied upon. Why should I not rely on them.

Further, Hahn told us that he answered the questions raised by Whitehurst regarding contamination and assured himself that there was no contamination of the evidence. Finally, Hahn relied on his belief that the defense had a copy of the Whitehurst Memorandum so that the defendant could call Whitehurst as a witness to elicit any of the information in the memorandum.

b. Discussion

(1) Hahn

Because Hahn was unaware of the Whitehurst Memorandum when he testified in the first trial, he cannot be faulted for failing to include it in his testimony.

Regarding Hahn's testimony in the second trial, Whitehurst alleges that Hahn committed perjury by reciting the MAU results without supplementing or amending them with the information in the Whitehurst Memorandum. Although we find no perjury, we conclude that the testimony was incomplete.

When one Laboratory examiner testifies to the results or conclusions of another examiner, the testifying examiner has a duty to report the results accurately and completely--whether he agrees or disagrees with his colleague's opinions. Although in 1990 Whitehurst concluded that RDX and PETN were on the fuel bladder and that, according to his dictation, he reached no other conclusions regarding explosives residue, Whitehurst stated in 1994 that he reached additional conclusions from a review of the data. It was beyond Hahn's expertise as an EU examiner, and beyond his discretion as a witness purporting to recite the results of another examiner, to selectively omit the 1994 conclusions because Hahn thought they were speculative or otherwise meritless. What was requested of Hahn on the witness stand was not his evaluation of Whitehurst's conclusions but merely a factual restatement of them. When Hahn was asked to state the MAU results, a complete answer would have been that the MAU chemist found RDX and PETN in 1990 but on a further review in 1994 also found that the data did not prove but was consistent with an ammonium nitrate explosive and thought that the significance of the data for RDX and PETN could not be determined without answering certain questions about contamination. Since Hahn believed that in 1994 Whitehurst reject[ed] the scientific findings made in 1990, Hahn's testimony about the 1990 findings was potentially misleading without the caveat that the author of the 1990 findings now had misgivings and additional findings.

We recognize that Whitehurst neither withdrew the original dictation nor submitted a supplemental dictation. Nor do we consider the Whitehurst Memorandum a complete rejection of Whitehurst's dictation. Nevertheless, when Hahn testified in the second trial, Hahn was aware that Whitehurst had reached additional conclusions supplementing those reflected in his 1990 dictation. To ignore the Whitehurst Memorandum because it lacked the form of a supplemental dictation would be an elevation of format over substance. At a minimum, Hahn had an affirmative duty to obtain explicit permission from a supervisor before he omitted reference to the Whitehurst Memorandum, because such omission was potentially incomplete and misleading. He failed to obtain such supervisory approval.

That Bender was comfortable with the original dictation is immaterial. Bender was a technician. Whitehurst, as the examiner, was responsible for the MAU results and conclusions. Moreover, all Bender could say was that the instrumental results were accurate--something Whitehurst never disputed. The Whitehurst Memorandum concerned additional conclusions concerning an ammonium nitrate explosive and the significance of the instrumental results--matters on which Bender was unqualified to comment.

Similarly, that Hahn believed there was no contamination did not justify omitting language Whitehurst used to qualify his conclusions.

Finally, that the defense may have had the Whitehurst Memorandum does not mean Hahn could ignore it in his testimony. Regardless of what the defense possesses, an examiner has a duty to present accurate testimony. By not testifying to the information in the memorandum, Hahn gave testimony that was incomplete. Moreover, Hahn did not know for a fact that the memorandum was

disclosed. Although Hahn told us I'm certain the prosecutor gave the memorandum to the defense, he also told us, A So, I mean, I don't really know, but I imagine that [Cheryl Pollak, the prosecutor] recognized that it was incumbent upon her to provide it [to the defense] and she discharged her duties. I have no reason to presume otherwise.

When one examiner testifies to another examiner's conclusions, the testifying examiner is only a messenger. He has no discretion to omit language supplementing or qualifying the conclusions, even if he believes the language is speculative or groundless. We recognize that Hahn was presented with a very unusual and difficult situation and that he received no guidance from his supervisors. We nevertheless conclude that he had an affirmative duty to resolve the controversy before he gave potentially incomplete and misleading testimony and that he therefore erred when he testified, without explicit supervisory approval, as though the Whitehurst Memorandum did not exist.

(2) Kearney

Although Hahn erred in his testimony, Kearney contributed to that error. Kearney told us he believed that the Whitehurst Memorandum would not affect the Laboratory results or Hahn's testimony. Yet Kearney recognized that in the memorandum Whitehurst was attempting to qualify his initial results, and Kearney thought that Whitehurst should have testified to his examination and results at trial. Had Whitehurst testified, the qualifications] to his initial results would have been put before the jury. Yet Kearney took no action either to cause Whitehurst to testify in the second trial or to tell Hahn to include the qualifications] in his own testimony if Hahn was asked to restate Whitehurst's conclusions.

Moreover, Corby supported much of Whitehurst's analysis, but we can detect no steps taken by Kearney to consult with other qualified experts to resolve the scientific issues. Without further review of the technical and scientific issues that had been raised, we do not see a valid basis for Kearney's decision to dismiss the concerns raised by the Whitehurst Memorandum.

One example of a scientific issue in the memorandum that Kearney dismissed without proper consideration related to Whitehurst's observations concerning the VOD necessary to cause pitting and cratering. Despite Corby's support for Whitehurst's position, Kearney apparently rejected Whitehurst's position without thorough scientific research and analysis.

The most glaring mistake made by Kearney was his failure to communicate to Hahn or Whitehurst, and document, any decisions he did make. Whitehurst waited but was never called as a witness in the first trial. He was not even informed of the second trial. Hahn heard nothing regarding his complaints about the memorandum and thus proceeded to the second trial with no further guidance on how to handle any questioning on this topic. If the memorandum had been turned over to the defense, questions regarding it were certainly possible at the second trial. Kearney should have informed Hahn of his reasoning in dismissing the concerns in the memorandum so that Hahn could be prepared to respond to defense questions. Instead, management left Hahn and Whitehurst totally unprepared for the embarrassing situation in which they might be forced to take the stand and contradict each other.

In sum, we conclude that Kearney erred in not properly resolving the issues raised by the Whitehurst Memorandum and not communicating his decisions to Hahn and Whitehurst.

3. Secondary Explosion

Hahn testified in both trials that, after the explosive device was detonated on the Avianca aircraft, a fire started resulting in a secondary explosion, which he described as a fuel-air explosion, that destroyed the aircraft. In the first trial he stated that Awe reached the conclusion as to what happened. By implication, this meant that Hahn reached the conclusion in consultation with the FAA and NTSB representatives at the crime scene. In contrast, in the second trial Hahn stated that the scenario he described was Amy conclusion. This statement of the conclusion is problematic because Hahn is not an expert in fuel-air explosions.

When asked by the OIG what experience he had in linking particular damage with the occurrence of a fuel-air explosion, Hahn stated, The FAA has conducted experiments where they've done fires on board an aircraft fuselage and have had areas of flashover, and I've seen videos of that. And other than that, and being aware of fuel-air explosions, I don't have any experience. Hahn further explained that he based his testimony on other experts and things that he had read about fuel-air explosions. Hahn readily admitted to the OIG that he was not an expert in fuel-air explosions.

We find Hahn's testimony in the second trial regarding fuel-air explosions to be beyond his own experience and expertise. As proof of his lack of expertise, we cite the fact that Hahn interchangeably refers to the secondary explosion as a fuel-air explosion or a flash fire. These two phenomena are not the same, and Hahn's use of the two descriptions interchangeably is incorrect. Hahn admitted that he was using the two words to mean the same thing; however, he clarified that what he was really talking about was a flashover or the point at which matter suddenly burns explosively. This distinction was not made in his testimony at trial.

Walter Korsgaard was the FAA representative who investigated the Avianca crash; he is an expert on fuel-air explosions on aircraft. Like Hahn, Korsgaard concluded that a fuel-air explosion occurred on the Avianca flight. Korsgaard's opinion as to what happened, however, differed from Hahn's in certain respects. Korsgaard's report states:

Based on the above evidence and various eye witness accounts, the following sequence of events can be developed:

- [1] IED [improvised explosive device] detonates in area under seat number 14F and frame station 783 on passenger cabin floor.
- [2] Passenger cabin floor penetrated.
- [3] Passenger cabin fuselage skin and top of center fuselage fuel tank middle bladder section penetrated.
- [4] Passenger cabin relatively slowly begins to decompress and pressurize[d] center fuselage fuel tank.
- [5] A fuel/air explosion and fuel ignition is initiated in top of center fuselage fuel tank spreading rapidly thru [sic] vent holes to right and left number 2 fuel tank wet wing sections and back into passenger cabin as pressure in fuel tank exceeds cabin pressure.
- [6] Structure integrity of center fuselage wing box section and right and left wet wing fuel tank sections of number 2 fuel tank bulkheads are violated.
- [7] Fuel in wet wing fuel tanks numbers 1 and 2 is ignited.

-- [8] The APU [auxillary power unit] located at rear of center fuselage wing box section is blown to rear of aircraft by the force of the fuel/air explosion within this center section fuel tank.

Korsgaard continues the sequence of events by describing how the aircraft broke up and came to the ground.

In the two trials and in his OIG interview, Hahn testified to a scenario different from Korsgaard's. Hahn agreed with the first three events described by Korsgaard: an IED detonated under seat 14F, breaching the center fuselage fuel bladder tank and the side of the aircraft. Then their accounts diverge. Hahn made no mention, as Korsgaard did (Event 4), that the passenger cabin relatively slowly beg[an] to decompress and pressurizes center fuselage fuel tank. In fact earlier in Hahn's testimony in the second trial he said that certain aircraft damage indicated rapid depressurization of the cabin.

The next event, according to Korsgaard (Event 5), was that a fuel/air explosion and fuel ignition is initiated in top of center fuselage fuel tank. According to Hahn, on the other hand, the next event is a fire that burned Adirty, throwing a lot of hot gaseous material into the air, a lot of hot matter into the air. According to Hahn, the fuel-air explosion did not come until later:

[W]hat I believe happened is that a small explosive device functioned, breaching the aircraft, opening the side of the fuselage, opening up the bladder box or the bladder fuel cells inside the wing, blasted and started a fire.

That fire burned for a number of seconds, probably in the neighborhood of a minute, at which point in time the hot gases and hot particula[te] matter from that fire caused the secondary explosion of fuel air explosion. That broke the aircraft apart.

Moreover, according to Hahn, the fuel-air explosion did not occur in the fuel tank, as Korsgaard stated, but rather inside the fuselage (first trial). As Hahn described it in his OIG interview:

So the fire [that was set off by the explosive device] is burning as that fuel is venting and it's burning not only fuel, but it's going to be burning carpeting and seat cushions and fabrics, rugs, whatever is there on board that aircraft. . . . [E]ventually it reaches a point where you have enough heat and hot gasses and hot flammable gasses and particulate matter in the air where it flashes over, and when it flashes over, the aircraft comes apart.

In the first trial and in the OIG interview, Hahn compared the fuel-air explosion in Avianca to a fuel-air explosion in a grain elevator, in which small particulate matter from the grain is suspended in the air. Korsgaard said nothing about particulate matter from the interior of the cabin playing a role in the fuel-air explosion.

Thus, Hahn's theory regarding a fuel-air explosion differed from Korsgaard's in three principal respects. The first difference related to the sequence of events: Korsgaard thought the event that followed the detonation of the IED was the fuel-air explosion and the fire, whereas Hahn testified that the detonation led to a fire that burned probably for about a minute and then the fuel-air explosion occurred. The second difference related to the location of the fuel-air explosion: the center fuel tank (Korsgaard) as opposed to the fuselage (Hahn). Finally, Korsgaard did not say, as Hahn did, that particulate matter played a role in the explosion.

Because Hahn is not an expert in fuel-air explosions, he should have simply testified to the opinion of Korsgaard (or to the opinion of another qualified expert)--with an attribution and without embellishment. Hahn ventured beyond his expertise when he developed and testified to his own theory of a fuel-air explosion.

4. Injuries to Passengers

Hahn testified in both trials that certain injuries observed on the passengers' bodies--hard, burnt skin and skulls that had been cracked open--supported his theory of a secondary explosion. In the first trial he stated that these injuries were consistent with extreme heat, flash-fire type of damage. In the second trial he stated the injuries were consistent with a flash fire or a fuel-air explosion. We conclude that this testimony was beyond Hahn's expertise and was incorrect.

Hahn told us that he drew the connection between these injuries and the flash fire because the only other place he had heard of the same type of injuries was in lectures regarding a flash fire at Dupont Plaza in Puerto Rico. He also told us that he was familiar with the subject matter because he attended lectures on fire damage by a former agent where this was discussed and had read articles about these same types of injuries and their causes. We conclude that this experience was inadequate to make him an expert on the relationship between the injuries and an explosion.

In fact, the injuries are not consistent with a flash fire or fuel-air explosion, which are of short duration. Rather, the injuries indicate that the bodies were subjected to substantial heat for a significant period of time. When we pressed Hahn on this point, he acknowledged that the injuries to the bodies did not justify the opinion that a fuel-air explosion occurred but rather that there was a hot fire burning for a continuous period of time. Hahn admitted that it might have been more accurate for him to say that the injuries to the bodies were consistent with his theory of how the fuel-air explosion came about--that is, that there was a preexisting condition (the continuous hot fire) which could have led to a fuel-air explosion. As Hahn also admitted, however, this preexisting condition would not always result in a fuel-air explosion, and a fuel-air explosion would not always require a fire such as the one he believed occurred in this case. Essentially, the injuries to the bodies told Hahn nothing about whether a fuel-air explosion occurred; they only told him that an intense fire burned for a period of time. This is quite different from his testimony that the injuries to the bodies were consistent with a flash fire or fuel-air explosion.

Hahn told us he thought he could render opinions about matters if AI know more than a layman, which is your test of whether or not you're an expert. He also stated that Aif I know the answer it would be permissible for him to respond to questions outside his expertise. As exemplified by this case, Hahn's views are incorrect and dangerous. All educated laymen are not experts. That a witness thinks he knows the answer to a question does not mean he does. To assure that erroneous and unreliable information is not presented in court, a Laboratory examiner must only answer questions within his expertise.

In sum, we conclude that Hahn's testimony about the injuries was misleading, inaccurate, and outside his area of expertise. We further conclude that he improperly used this testimony to support his theory of a fuel-air explosion.

5. Other Allegations

Concerning Hahn's testimony, Whitehurst makes numerous other allegations, which we will address summarily. Because Whitehurst makes the same basic criticisms to Hahn's testimony in both trials, the references below are to the second trial unless otherwise noted.

a. Whitehurst contends that Hahn misstated his qualifications and background. We conclude that

only one contention has merit. Hahn was not required to volunteer his major in college (English), and, when Hahn testified to his participation in scores of bombing cases, he was not required to volunteer the percentage relating to aircraft explosions.

Hahn also testified that A[m]y experience includes being called upon to do crime scene processing and make assessments of such notable causes of explosives [sic] in criminal cases such as Pan Am 103 over Lockerbie, Scotland and the World Trade Center in New York. This testimony overstated Hahn's experience. In the Pan Am 103 case, Hahn's only involvement in explosive assessments was that he examined the passengers' personal effects for blast damage. In the Trade Center case, Hahn's role was limited to management of the crime scene and did not include analysis of the evidence.

b. During his testimony Hahn was shown numerous photographs (most of which he took) of the aircraft wreckage and debris and a diagram of the aircraft, and he was asked to state his observations. Regarding one photograph he stated that Aon the inside wall of this fuselage is where we actually found charring and heat damage, which told us that, again, this side of the aircraft from the outside was not on fire, but inside smoke was filling out, circulating throughout the fuselage, and heating up terribly, melting down things on the inside of the aircraft on the left-hand side. (Emphasis added.) Although Hahn may not be an expert on fire damage to aircraft, his testimony here implicitly meant that the other experts at the scene, who do have expertise on this subject, participated in the assessment. Accordingly, we do not fault this testimony.

Regarding another photograph Hahn testified:

That is a wing of the aircraft and it show[s] very severe fire damage. That fire damage is very evident here (indicating) where you see this white area on the far right-hand side of the photograph, but that is actually where the aluminum has become oxidized from the heat. Cooked, if you will, almost to a boiling point.

We conclude that this testimony exceeded Hahn's expertise and was inaccurate. Hahn had no expertise in the oxidation of aluminum. Without a scientific examination of the white area, Hahn could not say categorically that it was the result of oxidation. In his OIG interview Hahn told us that the oxidation would not occur just from heat, as he testified at trial, but from the burning process in the presence of air (oxygen). Hahn had no scientific basis for saying that the aluminum was A[c]ooked . . . almost to a boiling point.

Regarding the diagram and other photographs, Hahn commented on the structure of the aircraft. Kearney felt Hahn drifted outside his expertise on some of this testimony. Some of Hahn's comments were merely descriptive, requiring no special expertise (debris at the crime scene, main landing gear). Other testimony, however, appears to require expertise that Hahn lacked (position on aircraft of fuel tanks, position and function of Awing box). Also, Hahn commented on what he perceived as non-explosive damage (deformation of fuselage by depressurization of aircraft). In these examples, Hahn should have made clear that he was basing his testimony on information received from other experts. In contrast, regarding the lack of information from the voice data recorder, Hahn testified that A[w]e believe the lines were cut by the detonation of the explosive device (emphasis added), implying that the assessment came, at least in part, from the aircraft experts at the scene.

c. We reject Whitehurst's contention that an EU examiner such as Hahn, because he is not a metallurgist, is unqualified to testify about his observations of unique explosive damage such as pitting and cratering. Such observations and conclusions are within a qualified EU examiner's

expertise. Similarly, Hahn was qualified to say that (1) a portion of the emergency exit was probably in . . . many pieces because it was situated near the seat of the explosive device, (2) certain damage was Aprobably impact rather than explosive pitting, and (3) the explosive pitting would occur within a certain distance of the explosive. We do not consider the latter comment fabricate[d] testimony, as Whitehurst claims.

d. We conclude that Hahn was beyond his expertise and inaccurate in his use of certain terms (the gas causing pitting and cratering was in the form of a plasma, the metal in the pits was crystallized, the explosive Semtex contains a butylene binder). These terms were unnecessary to Hahn's presentation and should have been avoided.

e. Contrary to Whitehurst's claims, Hahn, in our opinion, did not give fabricate[d] explanations of brisant explosives and the functioning of a high explosive (A[h]igh explosives function not by burning, but by molecular breaking apart). These were not unacceptable lay explanations for these matters.

f. We find no fault with Hahn's testimony about the uses of PETN and RDX and the composition of Semtex. In fact, these explanations track Whitehurst's dictation. Similarly, Hahn's testimony that Semtex and C-4 are not, and nitroglycerine is, impact sensitive was accurate.

g. Hahn testified as to how his duties differed from the duties of the NTSB and FAA representatives, by saying that his assignment was to determine whether an explosive device functioned on the aircraft and the duties of the others were primarily to determine whether the crash resulted from a mechanical failure. We think this testimony was slightly inaccurate. Needless to say, if it was determined that the crash resulted from a criminal act, the FBI would have been the exclusive agency of the United States to investigate the crime. But the NTSB and FAA are, without limitation, mandated to determine the cause of the crash, which would include an inquiry by them as to whether an explosive device was used.

h. Whitehurst expressed concern that Hahn's testimony showed that his presence at the DAS crime scene may have led to contamination of the Avianca evidence. Hahn, however, told us that he had sent the Avianca evidence to the Laboratory before the DAS Building was bombed.

i. In the first trial, after Hahn testified to the findings of RDX and PETN, he was asked whether those chemicals would be found in any other part of the plane other than an explosive device --in, for example, the seats or the paneling. Hahn replied:

They are both extremely unstable molecules, as any explosive would be. And they, in fact, they can break down with something as simple as sunlight. You would not find them in the environment, no.

This answer was partially inaccurate. Although RDX and PETN do not occur naturally in the environment, they are not extremely unstable and would not readily break down from sunlight under normal circumstances.

B. Whitehurst's Conduct

As explained below, we conclude that Whitehurst's conduct in this case was deeply flawed in several respects.

1. Overload

discredit the Confessor's claim that an ammonium nitrate gelatin dynamite was used on the aircraft. As Whitehurst told Hahn on June 4th, and as Whitehurst acknowledged in his memorandum, he would have expected to find residues of nitroglycerine (NG) on the evidence if a dynamite had detonated on the aircraft. (NG is a primary component of dynamite. See n.98, supra.) According to the Whitehurst Memorandum, however, no residues of NG were found on the specimens Whitehurst examined. Nevertheless, Whitehurst concluded in the memorandum that he could not disprove the dynamite claim. One of the reasons for this conclusion was that Whitehurst noticed in his 1994 review that the liquid chromatography test (LC) for PETN was overloaded, which may have obscured the presence of NG. Because, therefore, NG may have been present but not detected due to the overload, Whitehurst asserted in the memorandum that he could not eliminate the possibility of a dynamite.

What Whitehurst overlooked in his 1994 review, however, was that, in addition to the LC test, a thin layer chromatography test (TLC) was conducted. The TLC would have detected NG if present. It did not. A thorough review of the file by Whitehurst would have revealed this information. When we confronted Whitehurst with the TLC results, he admitted that he erred in not reviewing the TLC data in 1994 and in concluding that due to the overload he could not exclude the presence of NG. Thus, we fault Whitehurst for failing to conduct an adequate review of his own file prior to issuing his memorandum, a review that would have invalidated his theory that NG may have been present and was obscured by the overload.

With respect to his original 1990 examination, we also fault Whitehurst for failing to recognize the overload and run a second test.

2. Misstatement of the June 4th Conversation and of the Pertinent Issue

The Whitehurst Memorandum began with a summary of Whitehurst's June 4, 1994, conversation with Hahn about the Confessor. The summary, however, misstates the conversation on a material point. According to the memorandum, Hahn said in this conversation that the Confessor claimed to have used an ammonium nitrate based explosive (emphasis added) and that the damage was not consistent with an ANFO type explosive. (ANFO consists of ammonium nitrate and fuel oil.) In fact, as Whitehurst acknowledged in his OIG interview, Hahn said that the Confessor claimed to have used an ammonium nitrate based dynamite. When Whitehurst wrote the memorandum, he, of course, knew the claim concerned a dynamite, since he discussed dynamite throughout the memorandum, and he attached to the memorandum one of the Confessor's statements, which described the use of a dynamite.

One important difference between an ammonium nitrate based explosive and an ammonium nitrate based dynamite is NG, which is an essential component only of the latter. By misstating the June 4th conversation by omitting reference to a dynamite and by including reference to ANFO, Whitehurst made it seem that the important issue to be addressed in the memorandum was the use of an explosive that may not contain NG. As noted, Whitehurst detected no residues of NG on the evidence.

In the second paragraph of the memorandum, Whitehurst stated the following conclusion:

It is my opinion at this time that the data we acquired from analysis of the evidence provided to us in this matter does not disprove the use of an ammonium nitrate based high explosive and in fact is consistent with but not proof of the use of such an explosive.

Later in the memorandum, Whitehurst stated the basis for this conclusion:

The presence of white powder in the pits and the initial data consistent with the presence of nitrate and nitrite ions is consistent with though not proof of the presence of an ammonium nitrate based explosive.

This conclusion tracked Whitehurst's misstatement of the June 4th conversation and begged the real question in the case--namely, whether the data disproved or was consistent with the use of an ammonium nitrate based dynamite. As Whitehurst stated in his interview, The question that [Hahn] asked me was essentially, was an ammonium nitrate gelatin based dynamite used, or can you discredit that.

Because Whitehurst detected no NG residue, it would have been difficult for him to conclude that the evidence in fact is consistent with the use of a dynamite. We are unable to find that Whitehurst deliberately misstated the June 4th conversation to avoid that difficulty but still render an opinion that the evidence was consistent with a large class of explosives that would appear to include an ammonium nitrate dynamite. In any event, the conclusion about an ammonium nitrate explosive did not address the exact question asked by Hahn. Nowhere in the Whitehurst Memorandum does the author say that the data is consistent with an ammonium nitrate dynamite.

Whitehurst may have rendered an opinion that the data was consistent with an ammonium nitrate explosive because he thought this was the only conclusion justified by the evidence and he thought, in good faith, that he should set forth any conclusions he could reach. If so, he should have stated explicitly that he could not conclude that the data was in fact consistent with an ammonium nitrate dynamite, the Confessor's alleged explosive. As written, the conclusion is, at best, confusing, because it erroneously suggests that Whitehurst thought the data was consistent with the Confessor's story.

3. Validity of Opinions

a. Ammonium Nitrate Explosive

As noted, Whitehurst opined that the data (1) does not disprove, and (2) in fact is consistent with, an ammonium nitrate based high explosive. The first part of the opinion appears valid. Indeed, because all the remnants of the aircraft were not recovered and because the recovery did not begin until several days after the crash, it would have been virtually impossible to disprove the use of any explosive based on the residue analysis. Finding one or more explosives on the recovered residue (e.g., RDX and PETN) would not preclude the possibility that the residue of another explosive either was on an unrecovered remnant or, before the recovery began, was washed away by rain, was dislodged by the crash, decomposed, etc. The failure to find residue of an ammonium nitrate explosive, therefore, would not constitute proof that the explosive was not used on the aircraft.

In contrast, Whitehurst's opinion that the data in fact is consistent with an ammonium nitrate explosive is an overstatement by any reasonable measure. Whitehurst stated in the memorandum: The presence of white powder in the pits and the initial data consistent with the presence of nitrate and nitrite ions is consistent with though not proof of the presence of an ammonium nitrate based explosive. Whitehurst's technician found white powder in certain pits on the fuselage. This white powder possibly could have been ammonium nitrate. The technician, however, attempted to examine this powder instrumentally and was unable to determine what it was. The identity of the white powder is unknown.

As for the ions, Whitehurst's technician produced initial data consistent with the presence of nitrate

and ammonium ions on specimen Q13. A second test, however, could not confirm[] the presence of the ions. Accordingly, it is not certain that the ions were in fact present. In any event, because nitrate and ammonium ions occur naturally in the environment, the mere detection of them has only very limited probative value.

Whitehurst himself later maintained that similar results were not significant when he criticized certain work by David Williams in the Oklahoma City case. There, Williams stated in his report that A[a]mmonium ions and nitrate ions were found to be present on specimen Q171. This statement was apparently made in support of Williams' theory that ANFO was the main charge in the explosive device. Whitehurst had this to say about Williams' statement:

Why is Mr. Williams being allowed to introduce this into his report. He knows perfectly well that that means absolutely nothing at all. But the prosecutors will not. After an explosion the presence of nitrates are ubiquitous. Before an explosion nitrates are ubiquitous, everywhere. We are only now conducting background studies to determine just how prevalent. Many explosives give off ammonium. It means nothing, UNLESS TAKEN OUT OF CONTEXT.

(Capitalization in original; emphasis added.) When confronted with the contradiction between his comments about ions in the Avianca and Oklahoma City cases, Whitehurst could provide no explanation.

The laboratory notes in the Avianca case for specimen Q13 state that the ammonium and nitrate ions could not be reasonably associated because ammonium nitrate was not detected on a particular test and both ions could be formed by other than ammonium nitrate explosives. In his dictation, neither did Whitehurst mention the ions, nor did he say the data was consistent with an ammonium nitrate explosive.

Because (1) the white powder could not be identified, (2) the presence of the ions could not be confirmed, and (3) the ions have been found to occur naturally in the environment, we conclude that Whitehurst's statement that the data is consistent with the use of an ammonium nitrate explosive is overstated and suggests too strongly that such an explosive may have been used on the aircraft.

b. Ammonium Nitrate Dynamite

In his memorandum Whitehurst also opined that the data we have at this time cannot be used to successfully disprove the statement that a gelatin dynamite was used in this bombing. This opinion is valid for the reasons stated above concerning the inability to disprove the use of an ammonium nitrate explosive (failure to recover all remnants of the aircraft, etc.).

In his OIG interview Whitehurst addressed whether the data was consistent with the presence of an ammonium nitrate dynamite. He stated there was a weak consistency. He stated that the bases for this opinion were the factors discussed above regarding an ammonium nitrate explosive (the white powder and ions) and the fact that the presence of NG might have been obscured by the instrumental overload. As discussed above, Whitehurst's overload theory was invalid. Given Whitehurst's failure to detect NG residue and given the weakness of the data showing the use of an ammonium nitrate explosive, we conclude that Whitehurst's data did not warrant the opinion (given in his OIG interview) that the evidence was consistent with the use of an ammonium nitrate dynamite.

Whitehurst's data only allowed him to opine: (1) the data does not disprove the use of an

ammonium nitrate dynamite; (2) no data points to the use of a dynamite; (3) some data (the unconfirmed presence of ions and the unidentified white powder in the pits) have very limited probative value; (4) the ions (if they were present) could have come from an ammonium nitrate dynamite or from numerous other explosives or from the environment, and he cannot say which alternative is most likely; and (5) the unidentified white powder could have been ammonium nitrate or some other white substance, and he cannot say which alternative is most likely.

Thus, Whitehurst's opinion that the data was consistent with the use of an ammonium nitrate explosive was not only overstated but begged the real question--namely, whether the data was consistent with the use of an ammonium nitrate dynamite (the explosive the Confessor said he used). As to that question, we conclude that Whitehurst's data did not justify an opinion that the evidence was consistent with any dynamite. Accordingly, Whitehurst's conclusion in the second paragraph of the memorandum--that the data in fact is consistent with an ammonium nitrate explosive--was not only overstated, but also misleading, because it suggested, without a valid scientific basis, that Whitehurst's data supported the Confessor's story.

4. Contamination

Although not directly relevant to the discrediting of the Confessor's story, Whitehurst addressed in the memorandum whether possible contamination prevented the Laboratory from determining the significance of the data identifying the presence of RDX and PETN. In his original dictation Whitehurst stated:

Chemical analysis of specimen Q15 identified the presence of RDX and PETN high explosive. These two explosives are used in conjunction in the explosive SEMTEX. They also can be used in separate components of explosive systems.

It is the opinion of this examiner that the RDX and PETN identified on specimen Q15 originated either from an explosive such as SEMTEX or from a combination of components of an explosive system containing both PETN and RDX.

The Whitehurst Memorandum sets forth a series of questions about possible contamination at the crime scene, in transit, and at the Laboratory. See n.115, supra. Unlike Whitehurst's dictation, in which he opined that the RDX and PETN came from Semtex or an explosive system, in the memorandum he raised the question whether the RDX and PETN may have come from contamination rather than from the aircraft remnants before they were recovered in Colombia. Whitehurst asserted that the contamination questions need to be answered before we can determine the significance of the data -- that is, before it could be determined whether the RDX and PETN came from the aircraft or from contamination.

Whitehurst told us that when he wrote the memorandum, AI had no evidence at all about contamination. He stated, So what you've asked me is, do I know there was contamination. No, but I don't know there wasn't contamination. Whitehurst acknowledged that the contamination questions he raised were not specific to the Avianca case, but applied to any case involving organic explosives like APETN, RDX, TNT, nitroglycerine. Nevertheless, at the time of Whitehurst's March 1996 OIG interview, he had never raised these questions in any of his numerous cases, before or after Avianca, unless there was specific evidence of contamination.

Despite Whitehurst's assertion that he had no evidence at all about contamination when he wrote the memorandum, we think the circumstantial evidence available to him pointed to the unlikelihood that the PETN and RDX were present as a result of contamination. The RDX and PETN were both

found on the same specimen, and none of the other eight specimens contained either explosive. According to Whitehurst's original dictation, and the prosecution's theory, the substances were found together because they were components of Semtex or an explosive system used in the bombing. If, instead, the specimens had been contaminated by RDX and PETN, it would have been likely that the contaminants would have been randomly distributed on the specimens, producing contamination with either or both of the explosives on more than one specimen. In an OIG interview Whitehurst cited a 1995 contamination study in the Laboratory to show the real possibility of contamination there, but in that study, of the four locations that contained either RDX or PETN, none contained both substances. Although it is of course possible that there was contamination of a single specimen with two separate explosives and no other specimen was affected by either contaminant, this is not the likeliest scenario.

We question the manner in which Whitehurst raised the issue of contamination. We do not fault an examiner for raising a relevant issue at a late date if it does not occur to him earlier, and vigilance concerning contamination should be an integral part of the work of a forensic scientist. Here, however, the contamination questions raised in the Whitehurst Memorandum could and should have been addressed within the Laboratory before the memorandum was disseminated to a prosecutor in the middle of a trial. Hahn was knowledgeable about the procedures followed at the crime scene and how the evidence was transported to the Laboratory. Other personnel could have explained how the evidence was processed once it arrived at the Laboratory. Whitehurst should have addressed the contamination questions to these people before he disseminated the memorandum outside the Laboratory. Finally, Whitehurst should have noted in his memorandum that the lack of a random distribution of the RDX and PETN was indicative of the absence of contamination.

Since (1) the contamination issue was only indirectly relevant to contradicting the Confessor's story, (2) there was no affirmative evidence of contamination, (3) the circumstantial evidence was indicative of a lack of contamination, and (4) Whitehurst never wrote a memorandum with questions like these in any other case before or since Avianca, we conclude that Whitehurst erred when he raised the issue, in the manner that he did, for the first time in an ongoing trial.

Corby told us he would not have authorized the release of the information in the Whitehurst Memorandum to the prosecutor had he known Whitehurst had not contacted Hahn first. Nevertheless, it is apparent from the face of the memorandum that Whitehurst had taken no steps within the Laboratory to determine the validity of any of the contamination issues raised in the memorandum. We therefore conclude that Corby erred when he told Whitehurst to provide the information in the memorandum to the prosecutor without also directing Whitehurst to make the necessary contamination inquiries in the Laboratory first.

5. Circumvention of Hahn

Whitehurst wrote the memorandum on June 7, 1994, and gave it to Corby the next day. Corby reviewed it overnight and told Whitehurst on June 9, 1994, to give the memorandum to the prosecutor. That day Whitehurst gave the memorandum to an agent working on the case; he in turn gave it to the AUSA. Whitehurst did not consult with Hahn, or give him a copy of the memorandum, before it was disseminated outside the Laboratory.

Whitehurst justified his failure to consult with Hahn, or send him a copy of the memorandum, on his assertion that Hahn is a bully, will not listen to any reason at all, and does not receive information. We have already noted Whitehurst's error in failing to discuss the contamination questions with Hahn before disseminating the memorandum to the prosecutor. More generally, we

conclude that Whitehurst's failure to consult with Hahn on any issue, or at least send him a copy of the memorandum, before releasing it outside the Laboratory was unprofessional.

IV. Conclusion

A. Hahn

We conclude that in the Munoz trials Hahn did not commit perjury, fabricate evidence, or intend to mislead the court. We also conclude that he committed several errors: he erroneously testified in the first trial that no dynamite could have caused the pitting and cratering on the aircraft; he gave scientific opinions correlating the pitting and cratering with a VOD range that were unsound and not justified by his experience; before the second trial, he made no inquiries about the validity of his jetting theory, even though the literature attached to the Whitehurst Memorandum conflicted with that theory; he gave incomplete testimony concerning the MAU results; he testified incorrectly and outside his expertise concerning a fuel-air explosion, the injuries to passengers, and other areas; and he slightly overstated his experience. Hahn's conduct exemplifies the need (discussed in Part Six, infra) to train examiners to base conclusions on confirmed findings and validated theories and to testify within their areas of expertise.

B. Whitehurst

We conclude that Whitehurst committed several errors in connection with the Whitehurst Memorandum: he reached an invalid conclusion that an instrumental overload may have obscured the presence of NG; this error occurred because he neglected to thoroughly review the Laboratory file including the TLC results; he misstated his June 4, 1994, conversation with Hahn on a material point; he rendered a misleading and overstated opinion that suggested that his data was consistent with a potential defense; he raised questions whether contamination may account for his original findings of RDX and PETN, although there was no affirmative evidence of contamination, the circumstantial evidence was indicative of a lack of contamination, and he made no inquiries inside the Laboratory to determine whether his contamination concerns might have validity; and he released the memorandum outside the Laboratory without consulting with Hahn or at least sending him a copy. Finally, he also erred in his 1990 examination by failing to recognize the instrumental overload and run a second test. All of the errors in the memorandum tended to create problems for Hahn, the FBI, and the prosecution in an ongoing trial.

C. Kearney

We conclude that SAS Chief Kearney erred by not properly resolving the controversy raised by the Whitehurst Memorandum and by not communicating his decisions to Hahn and Whitehurst. After the second trial Kearney reviewed Hahn's testimony in that trial and felt Hahn testified outside his expertise regarding the construction of the aircraft and the injuries to the passengers. Kearney also erred by failing to discuss these matters with Hahn, and define and document the corrective action taken, to avoid such problems in the future.

D. Corby

We conclude that Corby erred when he authorized Whitehurst to release the information in the memorandum to the prosecutor without also directing Whitehurst to address the contamination questions to personnel inside the Laboratory first.

**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

**Appendix C Comet Accidents
(Unofficial)**

Source: <http://www.tech.plym.ac.uk/sme/FailureCases/FAILURE.htm>

Professor M Neil James - Web page <http://www.plym.tech.ac.uk/sme/uoa30/structur.htm>

Comet Airliner

Jet transportation age began in on May 5 1952 when the De Havilland Comet 1 began scheduled flights from London to Johannesburg. In April 1953, a Tokyo to London service was inaugurated – flying time for the 10 200 mile distance dropped from 85 hours to 36 hours. The Comet had a cruising speed of 490 mph at 35 000 feet and a range of 1 750 miles with a payload of 44 passengers.

Power came from 4 De Havilland Ghost turbojet engines of 5 000 lbf thrust. Engines were mounted in the wing root – this minimises yaw accompanying loss of engine on take-off, but poses a hazard in the event of engine fire/disintegration and does not allow for easy uprating of engines (cf. hanging engine pods under wing) – poor design for development. Fuel consumption of turbojets is lower at high altitude.

The cabin was pressurised to maintain a pressure equivalent to 8 000 feet at an aircraft altitude of 40 000 feet, which was required for efficient operation of the engines. This gave a pressure differential of 8.25 psi (56 kPa) across the fuselage – twice the value previously used. De Havilland conducted ‘many tests’ to ensure structural integrity of the cabin. Other innovations included high pressure refuelling, hydraulic actuation of control surfaces and cabin air conditioning. It seemed that the future was bright for the British aircraft industry, with orders from France, Canada and the UK.

However, a series of 3 accidents occurred where Comet aircraft disintegrated in flight:

G-ALYV after leaving Calcutta – May 1953. Violent storms were thought to be involved and some wreckage was recovered. No firm conclusions drawn as to cause.

G-ALYP over Elba – January 1954 after 1 286 cabin pressurisation cycles. Little wreckage was recovered and no major problems found in fleet inspection. Fire was assumed the most likely cause and modifications made to improve fire prevention and control. Aircraft returned to service.

G-ALYY flying as SA 201 after leaving Rome – April 1954.

A more intensive effort was made to recover the wreckage of G-ALYP using underwater television cameras for the first time. About 70% of the aircraft was recovered and reconstructed at Farnborough. The engines were recovered more-or-less intact, showing that engine disintegration was not the cause of the accident, and neither was any evidence of fire found.

Comet G-ALYU, which had experienced 3 539 flying hours and 1 221 cabin pressurisation cycles, was subjected to full-scale flight simulation testing at Farnborough. The fuselage was hydraulically

pressurised in cycles, while the wings were flexed with jacks to simulate the flight loads. Water was used for this pressurisation because calculations had indicated that the energy release under cabin rupture with air as the pressurisation medium was equivalent to the explosion of a 500 lbf bomb in the cabin. The cabin was also supported in water to avoid extraneous weight effects. After the equivalent of a total of 3 057 (1836 simulated cycles) flight cycles a 2 mm crack near the escape hatch grew to failure (Hatch Sketch). This was repaired and after 5 46 flight cycles a 4.5 m section of the cabin wall ruptured due to fatigue cracking. It was concluded that explosive cabin failure had caused the loss of the 3 Comet aircraft. Developing a detectable crack 6 mm long consumed some 95% of the cyclic life.

The Royal Navy was charged with getting the relevant fuselage piece of G-ALYP from the sea (using simulation trials, based on the way the aircraft was now thought to break up in flight, to establish the likely position of this part of the aircraft on the seabed. This was recovered within a few hours of searching and showed, in the language of the coroner, the 'unmistakable fingerprint of fatigue'. The fatigue crack was associated with the stress concentrations of the rather square rear ADF window cutout (stress of 315 MPa at edge of window), and with a bolt hole around the window (although the stress at the bolt position was only 70 MPa).

The Chief Designer at De Havilland had wanted to glue the windows in position, but the tooling for the square shape was too difficult to make. A lower stress concentration shape would have been easier to manufacture.

The manufacturer had performed fatigue tests of the forward cabin area at about 10 psi (with cracking occurring at 18 000 cycles), but these were carried out after static tests of to up to 16.5 psi (twice operating pressure) had previously been applied. Cracks were also known to be present after manufacture, and the remedy was to drill 1.6 mm holes at the crack tip to 'arrest' them (such an arrested crack was present near the rear ADF window, which had not propagated until the final failure).

Modifications were made to the design of the aircraft and the Comet 4 re-entered service in October 1958 on the trans-Atlantic route with 80 passengers. A few weeks later the Boeing 707 flew the same route with 120 passengers and a safer, more flexible design engine design. The loss of 6 years to the Comet problems may have been instrumental in losing the lead in future jet transportation to the US. Parity in sales of passenger aircraft was established only in 1999 between Airbus and Boeing.

Technological Outcomes:

Full-scale testing of aircraft structures utilised in future aircraft.

Better understanding of fatigue testing achieved, i.e. match service and test loads (no previous over-pressurisation cycles first).

Attention drawn to detectability/critical size issues for fatigue cracks in aircraft structures.

Concept of 'one-bay' crack tolerance in fuselage probably formulated.

Causes:

1. New technology introducing new load cases (high altitude flight for turbojet engines requiring cabin pressurisation).
2. Mis-match between service loads and fatigue test procedure.
3. Possible contribution from out-of-plane bending loads (bi-axial stresses).

Design Failures:

Improperly understood failure mode assessment procedures necessitated by implementation of new

technology.

Poor configuration due to wing root engine placement (very few other aircraft have had engines in this position), affecting uprating potential, fire hazard, and structural integrity in the event of engine disintegration.

References:

1. P A Withey (1997) Fatigue failure of the De Havilland Comet 1 Engineering Failure Analysis Vol. 2 No. 4 pp147-154.
2. J F Lancaster (1996) Engineering catastrophes: causes and effects of major accidents Woodhead Publishing.
3. Johannesburg Sunday Star Review, March 22 1992 p.11 Super-fast jet takes a dive.
4. <http://www.hq.nasa.gov/office/pao/History/SP-468/ch13-2.htm>
5. <http://surf.to/comet> (Note that some of the information here with respect to crashes is inaccurate, e.g. fatigue is referred to as 'crystallinity').

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Appendix D DC-10 Accidents
(Unofficial 1973 through 1996)

<http://www.taxiways.net/DC-10/history/52-37.html>
DC-10 losses

Date:	Registration:	DC-10 type:	Msn:	Fn:	Airline:
731217	EC-CBN	DC-10-30	46925	87	Iberia
740303	TC-JAV	DC-10-10	46704	29	Turkish Airlines
751112	N1032F	DC-10-30CF	46826	109	Overseas National Airways
760102	N1031F	DC-10-30CF	46825	81	Saudi Arabian Airlines
780301	N68045	DC-10-10	46904	44	Continental Airlines
790525	N110AA	DC-10-10	46510	22	American Airlines
791031	N903WA	DC-10-10	46929	107	Western Airlines
791128	ZK-NZP	DC-10-30	46910	182	Air New Zealand
810203	AP-AXE	DC-10-30	46935	172	Pakistan Airlines
820123	N113WA	DC-10-30CF	47821	320	World Airways
820913	EC-DEG	DC-10-30CF	46962	238	Spantax
831223	HL-7339	DC-10-30	46960	237	Korean Airlines
860810	N184AT	DC-10-40	46751	36	ATA (American Trans Air)
870110	5N-ANR	DC-10-30	46968	243	Nigeria Airways
870917	82-0190	KC-10A	48212	382	US Air Force
880521	N136AA	DC-10-10	47846	69	American Airlines
890719	N1819U	DC-10-10	46618	118	United Airlines
890727	HL-7328	DC-10-30	47887	125	Korean Airlines
890919	N54629	DC-10-30	46852	93	UTA
921221	PH-MBN	DC-10-30CF	46924	218	Martinair
930414	N139AA	DC-10-30	46711	105	American Airlines
960613	PK-GIE	DC-10-30	46685	284	Garuda Indonesia
960905	N68055	DC-10-10F	47809	191	Federal Express

Service Bulletin 52-37

Service Bulletin 52-37 was issued by Douglas on July 3rd 1972, three weeks after the Windsor incident in which the rear cargo door blew off and caused severe damages to the aircraft structure. These modifications suggested by Douglas included a completely new door locking system for the infamous cargo door. Several facts are still unknown, but neither Douglas nor the operators of the DC-10 took this service bulletin too serious. At this time, 49 aircraft were already manufactured and operated by following airlines:

<http://members.tripod.com/vicondisa/dc10acc.htm>

June 12, 1972

McDonnell Douglas DC-10-10 N103AA (fsn 46503/fn 05), American Airlines

Over Windsor, Ontario
Mechanical Failure due to Design Flaw/Human Error
Occupants: 67
Fatalities: 0

Following takeoff from Detroit, the rear cargo door blew off due to a door latch system that had been damaged by ground crew members. The loss of pressurization caused the cabin floor to buckle and damaged the hydraulic control lines of the aircraft. The captain, having trained himself in simulator sessions to fly the aircraft using its throttles (a method called “differential thrust steering”), made an emergency landing in Detroit.

November 3, 1973
McDonnell Douglas DC-10-10 N60NA (46700/14), National Airlines
Over Albuquerque, New Mexico
Mechanical Failure due to Operator Error
Occupants: 128
Fatalities: 1

At 39,000 feet over Albuquerque the cockpit crew experimented with the autothrottle system of their DC-10. Their experiments oversped the fans of the no. 3 engine, subjecting them to unusually high stresses and causing them to burst through their casing. Fragments of the shattered engine pierced the fuselage and depressurized the cabin, sucking one passenger to his death.

December 17, 1973
McDonnell Douglas DC-10-30 EC-CBN (46925/87), Iberia
Boston-Logan International Airport, Massachusetts
Wind Shear
Occupants: 168
Fatalities: 0

The DC-10 approached Boston Runway 33L in bad weather and reduced visibility. The aircraft struck approach lights 500 feet short of the threshold and collided with a dike. The right main landing gear was sheared off; the aircraft then skidded and came to a rest 3000 feet from the threshold. The aircraft descended fast due to wind shear, which had not been noticed by the crew during the landing.

McDonnell Douglas photo
March 3, 1974
McDonnell Douglas DC-10-10 TC-JAV (46704/29), Turk Hava Yollari - THY
Outside Paris, France
Mechanical Failure due to Design Flaw/Human Error
Occupants: 346
Fatalities: 346

The latch mechanism of the aft cargo door, the design of which was susceptible to damage, had been damaged before the accident. Before takeoff the door had not been secured properly. Shortly after takeoff from Paris, the door failed. The resulting depressurization led to the disruption of the floor structure, causing six passengers and parts of the aircraft to be ejected, rendering No.2 engine inoperative, and impairing the flight controls so that it was impossible for the crew to regain control of the aircraft.

November 12, 1975
McDonnell Douglas DC-10-30CF N1032F (46826/109), Overseas National Airways
New York-John F. Kennedy International Airport
Fire due to Foreign Object Damage and Mechanical Failure

Occupants: 139

Fatalities: 0

Shortly after accelerating through 100 knots, but before reaching takeoff speed, a flock of birds rose from the runway. The aircraft struck the birds, damaging the no. 3 engine's fan blades and causing rotor imbalance. This caused a failure of the engine casing and started a fire in the right wing. Partial loss of hydraulic power to the plane's systems from the failure of the no. 3 engine meant that the aircraft could not be stopped on the runway. The pilot-in-command steered the aircraft off the runway at a 40-knot speed; the main undercarriage collapsed and the aircraft came to rest against the shoulder of the taxiway.

January 2, 1976

McDonnell Douglas DC-10-30CF N1031F (46825/81), Saudia

Istanbul, Turkey

Weather

Occupants: 373

Fatalities: 0

Heavy landing in fog; careened off the runway.

March 1, 1978

McDonnell Douglas DC-10-10 N68045 (46904/44), Continental Airlines

Los Angeles International Airport, California

Mechanical Failure

Occupants: 200

Fatalities: 2

During acceleration for takeoff, an engine exploded. The flight crew did not believe the plane would be able to stop on the remaining length of runway and steered it off the runway during deceleration. During the turn one of the main landing gear struts broke off and the airplane caught fire in this area.

May 25, 1979

McDonnell Douglas DC-10-10 N110AA (46510/22), American Airlines

Chicago O'Hare International Airport, Illinois

Mechanical Failure due to Maintenance Error

Occupants: 271

Fatalities: 271 + 2 third-party fatalities = 273

The No. 1 engine and pylon, its mountings damaged by an improper maintenance procedure, fell from its position on the left wing just before aircraft rotation. The engine loss resulted in a loss of hydraulic pressure to the left-wing slats. The uncommanded slat retraction, combined with damage inflicted to the leading edge during the engine separation, created a condition of asymmetrical lift. When the damaged wing lost its lift the plane rolled on its side and crashed into a trailer park less than a mile from the end of the runway.

October 31, 1979

McDonnell Douglas DC-10-10 N903WA (46929/107), Western Air Lines

Mexico City-Benito Juarez International Airport, Mexico

Landing Accident due to Weather/Human Error

Occupants: 88

Fatalities: 72 + 1 third party fatality = 73.

The DC-10 crashed after a landing descent through foggy conditions. Cleared to land on Runway 23R, it instead touched down on 23L, which had been closed for repairs. The aircraft struck

excavation equipment and suffered substantial damage before crashing into a building.

November 11, 1979

McDonnell Douglas DC-10-30 XA-DUH (46937/152), Aeromexico

Luxembourg, Europe

Improper climb procedures/operator error

Occupants: 311

Fatalities: 0

While climbing to 31,000 feet the aircraft entered a sustained stall, from which it recovered at 18,900 feet. The aircraft suffered mild damage to its outboard elevators and portions of the lower aft fuselage.

Jon Proctor collection

November 28, 1979

McDonnell Douglas DC-10-30 ZK-NZP (46910/182), Air New Zealand

Mt. Erebus, Antarctica

Navigational Error

Occupants: 257

Fatalities: 257

On a sightseeing flight over Antarctica, the aircraft deviated from its course by 1.5 miles east of its intended position and crashed into the slope of Mt. Erebus. The aircraft was destroyed by impact and fire. Later investigation placed blame on the airline for changing the computer track of the aircraft without notifying the flight crew.

February 3, 1981

McDonnell Douglas DC-10-30 AP-AXE (46935/172), Pakistan International Airlines

Karachi, Pakistan

Ground fire

Occupants: 0

Fatalities: 0

Destroyed in a hangar fire.

January 23, 1982

McDonnell Douglas DC-10-30CF N113WA (47821/320), World Airways

Boston-Logan International Airport, Massachusetts

Landing accident due to weather and human error

Occupants: 212

Fatalities: 2

The aircraft touched down on an ice-covered runway 2,800 feet past the displaced threshold. When it became clear that the aircraft would not stop on the runway the crew turned the aircraft off at the end of the runway. The aircraft rolled into shallow water and the nose section separated.

September 13, 1982

McDonnell Douglas DC-10-30CF EC-DEG (46962/238, ex-N1034F), Spantax

Malaga, Spain

Landing Gear Failure/Fire

Occupants: 394

Fatalities: 50

The crew aborted the takeoff above rotation speed due to strong vibration. The aircraft overran the runway, crashed into a railway embankment and caught fire. The source of the vibration was later determined to be a failure of the recapped tread of the right nose wheel.

December 23, 1983

McDonnell Douglas DC-10-30 HL-7339 (46960/237, ex-N1033F), Korean Air Lines
Ground Collision due to Weather/Human Error

Anchorage, Alaska

Occupants: 3

Fatalities: 0

Under foggy conditions the DC-10 crew taxied onto the wrong runway and collided head-on with a Piper PA-31.

August 10, 1986

McDonnell Douglas DC-10-40 N184AT (46751/36, ex-N142US), American Trans Air
Chicago-O'Hare International Airport, Illinois

Ground Fire

Occupants: 0

Fatalities: 0

A mechanic, improperly handling a loose oxygen generator from a damaged passenger seat-back in the forward cargo hold, set off the generator. This ignited the seat covers, along with oil stored in the forward cargo hold. The fire eventually burned through the cabin floor.

January 10, 1987

McDonnell Douglas DC-10-30 5N-ANR (46968/243), Nigeria Airways

Ilorin, Nigeria

Training Accident

Occupants: 9

Fatalities: 0

While practicing touch-and-go landings, the aircraft overshot the runway and caught fire.

September 17, 1987

McDonnell Douglas KC-10A 82-0190 (48212/382), United States Air Force

Barksdale Air Force Base

Ground Fire

Occupants: 17

Fatalities: 1

Ground fire.

May 21, 1988

McDonnell Douglas DC-10-30 N136AA (47846/69, ex-ZK-NZL), American Airlines

Dallas-Fort Worth International Airport, Texas

Take-off Accident

Occupants: 254

Fatalities: 0

During the takeoff roll, the flight crew received indications that the flaps and slats were not in takeoff position. The crew attempted to stop the plane but ran out of runway space. The nose gear collapsed, causing major damage to the underside of the forward fuselage. The aircraft was removed from service and used for parts.

[View photos of the damage](#)

July 19, 1989

McDonnell Douglas DC-10-10 N1819U (46618/118), United Air Lines

Sioux City-Gateway, Iowa

Mechanical/Hydraulic Failure due to Engine Failure

Occupants: 298

Fatalities: 111

During cruise at 37,000 feet the number 2 engine suffered an uncontained failure due to an unnoticed fatigue crack in the stage 1 fan disk. The explosion sent shards flying through the rear of the plane, rupturing its hydraulic flight control lines. With the help of a secondary air crewman the flight crew was able to control the aircraft through differential thrust steering of the remaining engines, and eventually descended for an emergency landing at Sioux City. During the final approach the nose pitched downward and the right wing dropped; the aircraft skidded to the right, rolled inverted, caught fire and cartwheeled.

McDonnell Douglas photo

July 27, 1989

McDonnell Douglas DC-10-30 HL-7328 (47887/125, ex-HS-VGE), Korean Air

Tripoli International Airport, Libya

Landing Accident due to Weather

Occupants: 199

Fatalities: 75 + 4 third party fatalities = 79.

The aircraft approached in conditions of poor visibility and crashed short of the airport.

photo courtesy of Greg Drawbaugh

September 19, 1989

McDonnell Douglas DC-10-30 N54629 (46852/93), Union de Transportes Aeriens (UTA)

Over Sahara desert in Niger

Sabotage

Occupants: 171

Fatalities: 171

During climb on this flight from N'Djamena to Paris, a bomb planted in the baggage hold went off.

photo courtesy of Greg Drawbaugh

December 21, 1992

McDonnell Douglas DC-10-30CF PH-MBN (46924/218), Martinair Holland

Faro, Portugal

Landing Accident due to Weather/Human Error

Occupants: 340

Fatalities: 56

During approach, when the aircraft was switched from autopilot to manual mode, the airspeed fell and could not be restored before the aircraft touched the runway. The main gear struck the runway very hard, causing the right wing to separate and the aircraft to slide down the runway. It was later determined that the high rate of descent, coupled with a crosswind, exceeded the structural limitations of the aircraft.

April 14, 1993

McDonnell Douglas DC-10-30 N139AA (46711/105, ex-N80NA), American Airlines

Dallas-Fort Worth International Airport, Texas

Landing Accident due to Weather/Operator Error

Occupants: 202

Fatalities: 0

During landing in poor weather the aircraft was caught in a crosswind. The first officer wanted to perform a go-around but the captain took control and landed the aircraft. The plane drifted off the runway and came to rest in mud; the nose and left main gear struts collapsed.

Read the abstract of the NTSB report

November 26, 1993
McDonnell Douglas DC-10-30 YV-135C (46791/258), Viasa
Buenos Aires, Argentina
Landing accident
Occupants: unknown
Fatalities: unknown
Damaged extensively while overshooting the runway on landing at Buenos Aires. Put into storage.

June 13, 1996
McDonnell Douglas DC-10-30 PK-GIE (46685/284), Garuda Indonesia Airways
Fukuoka, Japan
Engine failure
Occupants: 275
Fatalities: 3
Immediately after takeoff the first stage fan of the number 3 engine separated. The takeoff was aborted and the DC-10 skidded off the runway. The landing gear and number 1 engine separated from the aircraft.

September 5, 1996
McDonnell Douglas DC-10-10CF N68055 (47809/191), Federal Express
Newburgh-Stewart International Airport, New York
Fire
Occupants: 5
Fatalities: 0
At 33,000 feet during a flight from Memphis to Boston, a fire began in the cargo area. The crew made an emergency landing at Newburgh 20 minutes later and evacuated the aircraft. Because of the cargo arrangement, the firemen could not reach the source of the smoke. An hour after it started, the fire burned through the fuselage and the tail separated.

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**Appendix E Boeing History
(Unofficial)**

1910: William Boeing buys Heath's shipyard on the Duwamish River. It becomes his first airplane factory. The first airplane flight is made over Seattle.

1915: Boeing has a hangar built beside Lake Union.

1916: Pacific Aero Products is incorporated, and Boeing buys 998 of the company's 1,000 shares. He moves the operation to his shipyard on the Duwamish River.

1917: Pacific Aero Products is renamed the Boeing Airplane Co.

1918: Boeing signs a contract with the U.S. Navy to build 50 HS-2Ls, a patrol flying boat.

1919: The B-1 mail plane, the first Boeing-designed commercial aircraft, makes its first flight.

1921: The company wins a contract to build 200 Thomas Morse MB-3A pursuit fighters.

1922: Edgar N. Gott, general manager of the Boeing Aircraft Co., tells workers they will each receive a \$500 insurance policy as a New Year's gift, the first known non-wage benefit at Boeing.

1926: The Army orders 25 PW-9C fighters, a version of the PW-9 with a heavier fuselage. The production version of the FB-5 carrier fighter makes its first flight. The 27 ordered by the Navy are rolled onto barges and taken to the USN Langley.

1927: Boeing Airplane signs a contract with the U.S. Postal Service to fly airmail between Chicago and San Francisco. The Boeing Air Transport, predecessor of United Airlines, is founded to operate the mail routes and run the new airline.

1928: Boeing Air Transport acquires 73 percent of Pacific Air Transport's stock and runs an airline up and down the West Coast.

1929: The stock markets crash and the Depression begins. Ellen Church, a registered nurse, joins the crew of a Model 80A flight headed to San Francisco and becomes the first woman flight attendant.

1931: Boeing Air Transport, National Air Transport, Varney Air Lines and Pacific Air Transport combine to become United Air Lines, providing coast-to-coast passenger and mail service. One way takes 27 hours.

Military contracts

1932: The P-26 Peashooter makes its first flight. It becomes known as the fastest air-cooled

pursuit fighter in the world.

1934: The U.S. Army corps asks for a design for a very heavy long-range experimental bomber. Boeing engineers begin work on the XB-15. Bill Boeing sells his shares, angry over the government forcing him to sell off the fledgling United Airlines and other parts of his empire.

1935: Model 299 (XB-17), prototype of the B-17, makes its first flight at Boeing Field. Reporters dub it the "Flying Fortress." A Model 299 makes a nonstop test flight from Seattle to Dayton, Ohio. A few months later, a Model 299 crashes in Dayton.

1936: Boeing buys 28 acres on Marginal Way in Seattle, between Boeing Field and the Duwamish Waterway. The International Association of Machinists Local 751 signs its first working agreement with Boeing Airplane.

1938: The Model 307 Stratoliner, the first American pressurized commercial transport, makes its first flight.

1939: The Civil Aeronautics Authority grants Pan American Airways permission to use the Model 314 Clipper for commercial service.

1940: Pan American Airways takes delivery of its first Model 307 Stratoliners.

1941: The U.S. Navy chooses a site in Renton as its new manufacturing facility. It later trades the facility to the Army Air Corps, and 1,119 B-29s are built there in record time. Engineering starts for 264 service-model B-29s. The first B-17s fly into combat with the British Royal Air Force. Japan bombs Pearl Harbor on Dec. 7, drawing the United States into World War II.

1942: The luxurious Stratoliners are stripped of their civilian finery and pressed into military service as C-75s. The first flights carry antitank ammunition and medical supplies to British forces in Libya. The Model 345, or B-29, bomber makes its first flight.

1943: Boeing builds branch plants throughout the Puget Sound area, in Aberdeen, Bellingham, Tacoma, Chehalis and Everett.

1945: The war ends and 30,000 Boeing employees lose their jobs.

Commercial jets

1952: At its Renton plant, Boeing begins building the Model 367-80, the jetliner and jet tanker prototype that becomes the Dash 80, or 707.

1958: Pan American World Airways takes delivery of the country's first commercial jet airliner, a 707-120. That same year, the U.S. Air force selects Boeing to assemble and test the Minuteman intercontinental ballistic missile.

The space race

1963: NASA selects Boeing to build eight Lunar Orbiter spacecraft. Boeing also helps develop a number of space projects, including the Saturn V rocket.

1964: Boeing begins building a space center in Kent. It competes with Lockheed to design the

SST, or supersonic transport.

1966: Boeing celebrates its 50th anniversary. It announces plans for a 490-passenger 747 jetliner and begins construction on a new plant in Everett. It wins the design contract for the SST.

1968: The first 747-100 is rolled out during ceremonies at the new Everett plant. Launched by Saturn V, Apollo 8 takes the first astronauts around the moon.

1969: The 747-100 makes its first flight, and Apollo 11 astronauts Neil Armstrong and Edwin Aldrin are the first humans to walk on the moon. President Nixon approves the construction of two SST prototypes by Boeing. Boeing also begins building the Lunar Roving Vehicle.

1970: Boeing begins work on the Airborne Warning and Control System planes, or AWACS.

1971: The "Boeing Depression" hits the Seattle area, caused by a recession, high costs for the 747 and cancellation of the SST. The company cuts its area work force from 80,400 to 37,200 in two years, prompting the famous billboard that read, "Will the last person leaving Seattle turn out the lights." But the company also begins to diversify.

1974: Boeing's work on NASA programs continues as it wins a contract to build components of the Hubble Space Telescope.

1975: Boeing introduces its personal rapid transit system in Japan. It carries 3 million people by the year's end. It delivers its first modified B-52D to the Strategic Air Command.

1977: Boeing delivers a modified 747 for use as a delivery vehicle for the space shuttle. It also begins work on the world's largest wind turbine.

1979: The Chinook CH-47D helicopter makes its first flight.

1982: The 757-200 jetliner makes its first flight.

1985: Boeing begins preliminary designs for the international space station.

1986: Boeing and Bell Helicopter Textron start building six prototypes of the V-22 Osprey tilt-rotor aircraft.

1987: Boeing wins a contract to build the living and working quarters for the international space station.

1989: The V-22 Osprey and the B-2 stealth bomber make their first flights.

1992: Phil Condit becomes president of the Boeing Co.

Mergers

1996: Boeing merges with Rockwell's aerospace and defense units. They are renamed Boeing North American and are to operate as a subsidiary.

1997: Boeing merges with McDonnell Douglas Corp.

2000: The company lays off nearly 30,000 workers from July 1998 to July 2000. In October, Boeing acquires the former Hughes Space & Communications Co. of El Segundo, Calif., from Hughes Electronics Corp. and renames it Boeing Satellite Systems.

2000: Boeing, which has endured a number of lengthy strikes, is hit with a 40-day walkout by its engineers and technical workers.

January 2001: Boeing confirms it is considering closing the Renton plant and consolidating some of its aircraft manufacturing in Everett.

February: Boeing hints it may move its headquarters. Company Chairman and CEO Phil Condit, fresh from economic meetings in Davos, Switzerland, says Boeing cannot be too reliant on one region -- or one national economy -- for its future.

March 7: Boeing says that wings for the proposed 747X jumbo plane will be made in Japan.

March 21: Boeing announces it will move its corporate headquarters from Seattle. It is looking at sites in the Chicago, Denver and Dallas-Fort Worth areas.

Sources: Boeing's Web site: www.boeing.com; The Associated Press

747: BOEINGS MASTERPIECE by Patrick Hoeverler

Today modern aviation is unthinkable without the Boeing 747, of which 1,193 aircraft have up to date been delivered. This unique giant has transported 2.2 billion people, which equals 40 percent of the world's population. 30 years ago only few experts believed in this monumental success. In those days the Jumbo Jet was seen as an exotic creature among the other planes, and it was even thought that the Boeing Company was risking financial ruin.

The 747 came into existence after Boeing lost the competition for a strategic airlifter for the US Air Force. The Air Force needed a strategic long-haul airlifter capable of transporting troops and heavy weaponry to Europe. The very desirable contract was, however, given to Lockheed in 1965 and led to the creation of the C-5A Galaxy. From today's point of view this was a stroke of luck for Boeing, because the company now had resources for a new "Mega"-Airliner. By the way, Lockheed only built 131 models of them Galaxy.

The 747 saga began in spring 1965, when Pan American World Airways, Pan Am, asked Boeing to develop a lengthened version of the 707, with a capacity for 250 passengers. However, this could not be done for technical reasons.

During talks with Boeing representatives Pan Am Boss Juan Trippe demanded a commercial airliner, which could transport 400 passengers over a distance of 5,000km. The new jet was also be used for the transportation of cargo, because Trippe was convinced that aviation was to be dominated by supersonic airliners ten years from then. In that case the 747 was to be an excellent cargo liner. A few days later Boeing President William Allen telephoned Trippe and asked whether he had been serious with this unusual idea. Trippe, who had throughout the development of the 707 proved to be a friend of technological innovations, just responded by saying, "I am serious." In December 1965 both men met to negotiate details. Thus the foundation to build this giant was laid.

On 13 April 1966 Allen and Trippe signed a sales contract for 25 aircraft costing of \$550 million. This was up to then the biggest single contract of any airline. Pan Am's decision was courageous, since the competition doubted vehemently the economic viability of the giant jet. It has to be added that the then 71year old Juan Trippe ordered the 747 during a booming air traffic. An annual growth rate of 15 per cent in passenger rates was predicted. It was Pan Am's plan to beat the competition with the 747, which could carry three times as many passengers as the 707. The recession in 1970, which was completely unexpected, and the oil crisis foiled these plans. The 747 created over-capacities, which are every airliner's nightmare. Most carriers preferred smaller aircraft: They were, however, afraid that the competition might buy the giant and in this way dominate on international routes. This is why mainly non-American airlines were queuing up outside the Seattle works.

Here Boeing Boss Allen appointed Mel Stamper to be head of the world's biggest aircraft-project. For four years Stamper was in charge of the approx. 50,000 staff working on this program. He only took one day off, one Christmas Eve. The work load was so immense that he was often unable to return home and had to spend the night on a conference table in his office. Because of his leadership style his co-workers remembered him as a drill sergeant of the US Marines rather than as a manager.

In August 1965 Joseph Sutter joined the team as Chief Designer. After the program launch in March 1966 Sutter and his team looked at 50 different designs with two decks. The double-decker design was not ideal, because passengers could not be evacuated in the time prescribed by the American Aviation Authority FAA. After viewing an improvised mock up of a cabin, which was uncovered, Trippe discarded the double deck idea. The view from the improvised top deck had given almost everybody present vertigo. It is obvious why everyone involved, apart from one Pan Am pilot, refused to use the attached emergency escape slide. After this sobering experience Trippe wanted to look at the 1:1 model of a conventional single deck, which was still being constructed. This design already had the famous hump, which was to be the trade mark of the 747. It goes without saying that the hunchback attracted many sarcastic comments. It was alleged that Boeing designed the hunchback to enable wealthy captains to sit on their thick wallets and not bump their heads.

There was a practical reason for the distinctive curve. Trippe had asked for the cockpit to be situated above the cabin. This was going to make loading easier. The space behind the cockpit was allocated to the air conditioning system and other instruments. However, businessman Trippe had other ideas. "This space is reserved for passengers. Couldn't we install a bar there?" Sutter agreed with this idea, but other ideas like glass nose for first class passengers only caused everyone to shake their heads. Impressed with the size of the cabin, there were many suggestions as to how to use it, i.e. a restaurant, cinema, hairdressing salon or even a casino.

The aircraft of the superlatives was now in need of a production hangar of equally breathtaking dimensions. The existing works like Renton, in which the 707, 727 and 737 were assembled, were not big enough. The search for a suitable location had started as early as October 1964; it was intended for the planned for C-5. A commission examined 50 locations to their suitability, until Bill Allen decided on a site in Everett, which is located north of Seattle in Washington State. All along Everett had only ranked on fifth place. It did have an existing airport, Fairfield, but there was no rail link. The second steepest rail track in the USA had to be built at a cost of \$5 million dollars. With the launch of the 747 the start of the world's biggest industrial building was given. It was big enough to house 40 football fields measuring 5.5 million sq m. Over 2,800 workmen battled against the elements, months of rainfalls and snowstorms made the building works extremely difficult. During rains lasting 68 days, an enormous mud slide covered part of the site. It cost

another \$5million dollars to clear up the mess. In order to stay within the tight schedule, the construction of the 747 was started, although the factory had not been finished.

The 747 team was under enormous pressure to succeed, not only because the factory had cost \$200 million. There was an Anti-Jumbo-Lobby, which questioned the safety of the big aircraft, arguing that a single crash of one of the new Boeing models would cause as many casualties as all airliner accidents in any one year. Some "experts" even demanded that the 747 should only be allowed to fly in storm free corridors, because it would not be able to weather any turbulence because of its size.

In order to cut down any accident risk, Boeing used the so-called "Fault Free Analysis". A team of five engineers was occupied for months and compiled diagrams examining the effects of a failing instrument or the effect of one fault on all systems. According to Sutter safety was given the utmost priority, even the coffee makers on board were checked thoroughly. Never before had Boeing invested so much time and money into laboratory and wind channel tests. Amongst other things the engineers built two 747 models of three meter length, which corresponded with a complete Douglas DC-6. The wind channel test program was supposed to take 15,000 hours.

After basic design work and more than 75,000 construction drawings, which were carried out by hand, had been completed, the 4.5 million parts of the first 747 had to be assembled. Workmen very often cursed the monster, which they had to build. However, they were also proud of the product and their own achievement. Stamper was most impressed by their thirst for action and suggested to call the team in Everett the "Incredibles". To Stamper's amazement this nickname soon appeared on helmets and coats worn by the employees. Stamper remembers, "It was the most motivated workforce I have ever seen. Some chaps even worked two shifts one after the other without being asked."

The "Incredibles" had indeed performed a miracle. Less than three years after the contract was signed Jumbo 001 left the hangar in Everett with a big fuss on 30 September 1968. To celebrate the day 26 stewardesses, who were responsible for the first customers "beheaded" bottles of champagne and christened the first 747 "City of Everett". A Boeing 707, 727 and 737 flew overhead and made the celebrations perfect.

747-100 prototype rolls out

Prior to her maiden flight Jack Waddell, head of the test program, had made a movable mockup in order to simulate the way the 747 would roll on the ground, since a cockpit more than 10 meters above ground was very unusual in those days. The monstrosity was jokingly named "Waddall's Wagon" by Boeing employees. Strain trials, which were carried out to take the wind out of the critics' sails, went quite spectacularly. In one test the wings of a static plane were being bent upwards and only broke at 7.9 meters.

On 9 February 1969 it became obvious that the \$1 billion cost for developing the 747 had been worthwhile. Jack Waddell, Brial Wygle and Jesse Wallick took to the skies in Jumbo N7470 only two months behind schedule. Pilot Waddell was enthusiastic about the aircraft's flight properties, "This plane is the answer to every pilot's dream." And it was said beforehand that the aircraft was simply too big to fly safely. One was even concerned that the 747 might damage the tarmac because of its weight.

During test flights it became apparent that there were grave problems with the original version of the Pratt 7 Whitney JT-9D. During the 1,400 hours flight and 1,013 flights of the test program, the

engines were exchanged 55 times. However, the Jumbo finally received its certification through the FAA on 30 December 1969. When the "Baby Boeing" 737 was being tested, there was only engine change. Four of the five test aircraft were later fitted with airline interior and supplied to customers. The first 747 stayed with Boeing for further test purposes.

Pan Am took her first 747 into service on 21 February as scheduled. "Clipper Young America" was supposed to fly 336 passengers from New York to London. However, an "obstinate" door and problems during loading the cargo made the flight late. When the Jumbo finally rolled out to take off, one of the engines overheated. The aircraft finally had to be replaced. The substitute 747 took off after a delay of seven hours. This would not be one off occurrence. Delays and cancelled flights soon gave the 747 the nickname "Dumbo Jet", the flying white elephant. At the beginning of the 70s problems with the engines went so far that up to 30 completed Jumbos had to be stored in Everett with concrete blocks instead of engines under their wings. Moreover there were rising costs and delays in supplying the aircraft. The tight schedule was to blame for this, because it was simply unrealistic to build up a new organisation, a new production plant and a new aircraft all at the same time in only 34 months.

Boeing's bad luck did not seem to change. The company's vital nerve was hit badly by the 747 crisis, the discontinuation of the super sonic airliner program SST and declining orders. It was initially planned for the profits of the 707s and 727s to keep the 737 and 747 projects afloat. However, the Board of Directors in Seattle were not able to predict the impending recession. The result was debts amounting to \$1 billion. Boeing reduced its staff from 100,000 in 1968 to 38,000. This rigorous reduction and the sales success of the 727-200 led Boeing back on the road of success.

Pratt & Whitney was finally able to remedy the existing engine problems. As a result the Jumbo's reliability increased impressively. Half a year after its service, the 747-Fleet had already transported one million passengers. From 1970 Boeing expanded its program by taking on the 747-200 with wider range and bigger payload. It also offered the aircraft with different engines, i.e. Pratt & Whitney JT9D, General Electric CF6 and Rolls Royce RB524. The 747-200 became the most popular model with 393 models and was only beaten by the 747-400. Later the 747SP Special Performance followed for extremely long distances and the 747-300 with lengthened upper deck for up to 69 passengers. The program has for now been brought to a conclusion with the 747-400 with two-man cockpit, modern avionics and more powerful engines.

During the Superjet's 30th anniversary celebrations Sutter, now retired Executive Vice Director, said, "From the beginning the 747 was intended to be versatile. That is why she did adjust to new technologies and our customers' requirements over decades. This flexibility contributed towards the plane's success and makes it legendary." Currently Boeing is investigating the 747-400X with an increased take-off weight of 409.5 tons. This version can fly 740 km further than the ordinary 747-400. According to Ed Renouard, Vice President and General Manager of the 747/767 Program, who spoke during the celebration in Everett, lengthened versions are being considered. "The 747's evolutionary possibilities will without doubt enable us to continue building versions of the Jumbo for the next 30 years," explained Renouard.

Although orders are currently receding because of the Asian economic crisis, the Boeing 747 remains the flagship of the world's largest constructor. It is possible that the introduction of the Airbus A3XX in 2005 will take the lead of the Jumbo Jet. Until then the Boeing 747 is and remains a prime example for technological performance.

Instantly recognized by passengers around the world, the Boeing 747 is in a class by itself. The

747-400 continues the 747 family legacy by integrating advanced technology into one of the world's most modern and fuel-efficient airliners. Currently, the only model in production, the 747-400 incorporates major aerodynamic improvements over earlier 747 models, including the addition of winglets to reduce drag, new avionics, a new flight deck and the latest in-flight entertainment systems.

The improved and advanced 747-400 delivers more range, better fuel economy and lower operating costs than the previous 747 models. The 747-400 has a range of approximately 8,300 statute miles (13,360 km) and the lowest cost per seat-mile of any twin-aisle airplane offered by any manufacturer. It has a dispatch-reliability rate of 98.8 percent.

Boeing delivered the first 747-400 in 1989 to Northwest Airlines. Since the first 747 delivery in 1969, Boeing has delivered more than 1,230 747s, of which 500 are high-technology 747-400s. The 747's longevity and popularity are based on its unbeatable low seat-mile costs, flexibility, long-range dominance, unmatched comfort options and ability to integrate new technology.

Aerodynamics and Structural Materials

The 747-400's most noticeable aerodynamic improvement is the 6-foot longer wing with a 6-foot-high winglet angled upward and slightly outward. This change reduces fuel burn and extends the airplane's range. While designing the 747-400, Boeing engineers discovered that the kind of wing shape needed by the airplane created a whirling pattern, called a vortex, at the wingtip while the airplane moved through the air at cruising speed. The top part of that whirling movement of air actually pushed down on the top of the wing, creating drag.

Initially, it was thought that the problem could be solved by adding several feet to the wing, but that would make it difficult to navigate increasingly crowded airport taxiways and ramps. Longer wings also would reduce the number of airport terminal gates available to the 747-400. The acceptable solution came in the form of a compromise that involved lengthening the wing by 6 feet and adding the winglet.

The winglet provides the effect of having an even greater wingspan without outgrowing the standard airport slot. The wingtip extension and winglet offer a fuel mileage improvement of about 3 percent, which during the lifespan of an airplane amounts to considerable savings for the airlines and their passengers. The durable and lightweight winglets are made of graphite-epoxy materials, currently used on the Boeing 737, 757, 767 and 777 airplanes. The composite and aluminum winglet saves 60 pounds (27 kg) per airplane compared to an all-aluminum structure.

Boeing also recontoured the wing-to-body fairing for drag improvement and achieved additional efficiency from newly designed nacelles and struts for the airplane's advanced engines: the General Electric CF6-80C2, the Pratt & Whitney PW4000 and the Rolls-Royce RB211. These engines provide up to 62,000 pounds of thrust.

Use of advanced materials allows considerable structural weight reductions throughout the 747-400. Metal flooring, previously used in the passenger cabin, has been replaced by light, tough graphite composite floor panels.

Structural carbon brakes are standard on the 747-400's 16 main landing-gear wheels. They provide improved energy absorption characteristics and wear resistance, as well as an estimated 1,800-pound (816 kg) weight savings over previous brakes.

The 747-400 also achieved weight savings of approximately 4,200 pounds (1,900 kg) by using higher-strength aluminum alloys with improved fatigue life. These alloys, introduced on the 757 and 767, are incorporated in the 747-400's wing skins, stringers and lower-spar chords.

Flight Deck

The 747-400 flight deck provides flexibility that is being incorporated in more models across the Boeing fleet. The 747-300 three-crew analog cockpit was transformed into a fully digital, two-crew flight deck with cathode ray tube (CRT) displays. Six 8- by 8-inch (200 by 200 mm) CRTs

are used to display airplane flight control, navigation, engine and crew-alerting functions. They allow more information to be displayed with fewer instruments. The number of flight deck lights, gauges and switches was reduced to 365 from the 971 on the 747-300. Flight crew workload is designed to be one-half to one-third that of former 747 models.

In the event of an individual CRT failure, automatic or manual display switching is used as a backup. The Engine Indicating and Crew Alerting System (EICAS) can call up the status or schematics of various systems at any time on one of the CRTs. Crews now can obtain an update of the airplane's mechanical condition while in flight, whereas before the information only was available to maintenance workers when the airplane was parked.

Interior Design

Boeing redesigned the interior of the 747-400 to improve passenger comfort, convenience and appeal. Ceiling and sidewall panels were recontoured with new, lighter-weight materials that provide an open, airy look. Passenger stowage capacity increased to 15.9 cubic feet (0.4 m³) in each 60-inch (152 cm) outboard stowage bin, or 2.9 cubic feet (0.08 m³) per passenger.

New laminate materials were designed to meet Boeing fireworthiness goals. A new thermoplastic blend reduces smoke and toxicity levels in the event of fire, and upper-deck ceiling panels are made of improved polyester and phenolic sheet molding materials instead of polyester.

Interior flexibility allows airline operators to relocate class dividers and galley and lavatory modules more quickly to serve market requirements. Lavatory installation is simplified by a vacuum waste system, and additional locations for galleys and lavatories are available. These "quick-change features" allow major rearrangement within 48 hours, while seats and compartments can be changed overnight.

Boeing also revised the 747-400 air-distribution system. This increases the main deck cabin air distribution zones from three to five, which allows ventilation rates in each zone to be regulated based on passenger density.

For the first time on any airliner, an optional cabin crew rest area uses space in the rear of the fuselage above the aft lavatories. This area, which can be configured for eight bunks and two seats, provides privacy as well as comfort for off-duty flight attendants. By relocating the crew rest to this area, 10 more profit-making seats are available on the main deck of the aircraft.

Increased Range and Flexibility

An optional 3,300-U.S.-gallon (12,490 L) fuel tank in the horizontal tail boosts the 747-400's range an additional 400 statute miles (650 km). The 747-400 also has a new 1,450-horsepower auxiliary power unit (APU) that provides an estimated 35 percent to 40 percent reduction in fuel consumption, better air pressurization performance on hot days, higher electrical output and reduced noise levels. Mounted in the rear fuselage, the APU supplies pressurized air for air conditioning and engine starting while the airplane is on the ground, plus electrical power to operate lights and other requirements during stops. The new APU also can be retrofitted to earlier 747s.

The 747-400 is available in passenger, combi, freighter and domestic configurations. The 747-400 Combi is two airplanes in one, carrying both passengers (forward) and cargo (aft) on the main deck. The 747-400 Freighter is the largest commercial cargo transport in service, and the 747-400 Domestic is a high-capacity (568 passengers) airplane that incorporates structural improvements to accommodate the increased takeoff and landing cycles of short-range operations. Because it does not need the drag-reducing capabilities of the 747-400's longer wing and winglet, the 747-400 Domestic uses the same wings as the 747-100, -200 and -300 models.

Boeing 747 marks 30 years in service

Jan. 21 marks the 30th anniversary of the Boeing 747. To date, 1,238 have been delivered, more than any other widebody jet in history. Eleven-hundred are still in service, 500 of which are the high-technology 747-400. In November 1999, the 747 received its own U.S. postage stamp,

recognizing its place as one of the top three aviation achievements of the 20th century. Parts of the aircraft are made in Wichita.

The first 747, the 747-100, rolled out of the Seattle works on 30th September 1968, and flew on 9th February 1969. The first commercial flight was with Pan Am between London and New York on 22nd January 1970.

The 747-200 is a heavier version, which entered service with KLM Royal Dutch Airlines (the oldest name in the airline business, incidentally) in February 1971. Its increased weight and improved range stemmed mainly from an increase in the fuel load. A freight version, the -200F, appeared in April 1972, together with a short-range high-capacity version for the Japanese domestic market, the 747SR. This carries 523 passengers.

1973 saw the start of planning for the 747SP, the first example appearing on 19th May 1975 with the first flight on 4th July. This is a special performance version, produced for services where the prodigious passenger-carrying capacity of its longer sisters is unnecessary. The aircraft is nearly 14.5 m shorter than the standard version, the tailfin some 1.5 m taller, and the tailplanes 3 m longer. Pan Am was the first customer for this, too. The last example of 45 was built in 1982.

In 1982 the upper deck of the -200 was stretched by 7 m to produce the 747-300. This first flew on 5th October 1982, and the initial customer was Swissair. The modification was also applied to existing 747's. The current production version (pricelist on Boeing's website - some \$170 million - delivery included?) is the 747-400. Built with a fully EFIS cockpit (i.e. electronic instruments and fly-by-wire technology; pictured right) it needs two flight crew rather than three, and is lighter than its predecessors because of the widespread use of composite materials. It might look like aluminium.... The winglets are a characteristic feature, there is a long upper deck, and there is increased fuel capacity compared with previous versions. The high capacity -400D takes 566 passengers and is the present version of the 747SR. There is also a freight variant, the -400F.

The mid-1960s was a propitious time to begin developing a large airplane. Helped by affordable fares, air-passenger traffic was growing explosively. Increasingly crowded skies and the availability of large-thrust engines added to the incentive for creating the giant 747.

Boeing had a start on the design and technology of such an airplane because the company had bid on, but lost, the contract for a gigantic military transport, the C-5A.

When Boeing approached the airlines about a 550-seat jetliner in 1966, Pan American placed a \$525 million order for the new 747 almost immediately.

To build the new plane, Boeing constructed a \$200 million plant in Everett, Wash., 30 miles north of Seattle. The world's biggest airliner would be assembled in the world's largest building (by volume).

The 747 was truly monumental in size. The fuselage of the original 747 was 225 feet long; the tail as tall as a six-story building. Pressurized, it carried a ton of air. The cargo hold had room for 3,400 pieces of baggage and could be unloaded in seven minutes. The total wing area was larger than a basketball court. Yet the entire global navigation system weighed less than a modern laptop computer.

Later, derivatives of the basic 747 were offered. The 747-200 can carry approximately 440 passengers about 5,600 nautical miles. The 747-300 has an extended upper deck and is designed to

be more cost-effective to operate than the 747-200.

The latest model, the 747-400, rolled out in 1988. The largest of all commercial jetliners, it uses advanced technology throughout, especially in the all-digital flight deck, where only two crew members are needed instead of the usual three. The wingspan has been increased by 18 feet to a total of 212 feet, with 6-foot-high "winglets" on the wing tips. The 747-400 also is produced as a freighter, as a combination freighter and passenger model, and in a special domestic version, without the winglets, for shorter-range flights.

BOEING 747-200B

No. of passengers: 281-372

Crew: 8-15

Engines: Four 21 300 kp

Pratt & Whitney turbofan

Cruising speed: 890 kmph

Range: 10 400 km

Remarks: Long-range aircraft

Period of operation for SAS: 1971-1983

4 x 244 kN Pratt & Whitney JT9D-7R4G2

Dimensions and Weights

Span 59.6 m Landing gear track 11.0 m Max ramp weight 379,210 kg Max payload (kg) 69,400

Length 70.7 m Wheelbase 25.6 m Max take-off weight 377,850 kg Range w/ max payload 11,000

Height 19.3 m Turn radius 42.8 m Max landing weight 255,830 kg Max fuel (kg) 43,110

Wing Area 512 m² Wing Sweep 37.5° Max zero-fuel weight 238,820 kg Range w/ max fuel (km) 13,690

Empty weight 170,400 kg Max fuel (litres) 198,380

Performance

FAR Field Lengths Speeds

Take-off Landing
ISA sea level 3,190 m ISA sea level 1,890 m V2 speed 177 kt

ISA +20°C sl 3,610 m ISA +20°C sl 1,890 m VAT speed 141 kt

ISA 5,000 ft 2,130 m VNO speed 375 kt MNO speed M 0.92

ISA +20° 5,000 ft 2,130 m ISA = International Standard Atmosphere

Cruise Performance and Accommodation

Cruise Long range Cabin Cargo compartments

Max speed 507 kt Max speed 484 kt Max seats 550 Hold volume 175 m³

Altitude 35,000 ft Altitude 35,000 ft Seat pitch 76 cm/30.4" No of holds 3

Fuel cons./h 12,990 kg Fuel cons./h 10,700 kg Abreast 10 Press diff (bar) 0.60

BOEING 747-400 COMBI

No. of passengers: 209-230

Crew: 8-10

Engines: Four 24000 kp

Pratt & Whitney turbofan

Cruising speed: 890 kmph

Range: 10400 km

Remarks: Boing 747 with cabin divided and the aft section used for cargo.

Long-range aircraft

Period of operation for SAS: 1977-1987

4 x 254 kN Pratt & Whitney PW4056 or 251 kN General Electric CF6-80C2B1F or 264 kN Rolls Royce RB.211-524H

Dimensions and Weights for Pratt & Whitney powered aircraft

Span 64.5 m Landing gear track 11.0 m Max ramp weight 397,730 kg Max payload (kg) 49,140

Length 70.7 m Wheelbase 25.6 m Max take-off weight 396,830 kg

Height 19.3 m Turn radius 42.8 m Max landing weight 285,710 kg

Wing Area 511.2 m² Wing Sweep 37.5° Max zero-fuel weight 256,240 kg Range w/ max fuel (km) 12,390

Empty weight 184,080 kg Max fuel (litres) 216,852

Performance for Pratt & Whitney powered aircraft

FAR Field Lengths Speeds

Take-off

Landing

ISA sea level 2,073 m

ISA +20°C sl 2,073 m

ISA = International Standard Atmosphere

Cruise Performance and Accomodation

Cruise Long range Cabin Cargo compartments

Max speed 496 kt Max seats 266 Hold volume 170.7 m³

Altitude 35,000 ft Seat pitch 81 cm/32.4" No of holds 3

Abreast 10 Press diff (bar) 0.60

**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

Appendix F Cargo Door Incidents

(FAA, NTSB databases)

Difficulty Date : 10/11/00 Operator Type : Air Carrier ATA Code : 5210 Part Name :
CONTROLLER Aircraft Manufacturer : BOEING Aircraft Group : 747 Aircraft Model : 747422
Engine Manufacturer : PWA Engine Group : 4056 Engine Model : PW4056 Part/Defect Location :
CARGO DOOR Part Condition : MALFUNCTIONED Submitter Code : Carrier Operator Desig. :
UALA Precautionary Procedure : NONE Nature : OTHER Stage of Flight : INSP/MAINT District
Office Region : Western/Pacific US office #29 A/C N Number : 199UA Aircraft Serial No. :
28717

Discrepancy/Corrective Action: Fwd cargo door opened by itself when cb pushed in. On arrival, circuit breakers were pushed in, when pressure relief door handle was opened the door latches opened and then the door opened on its own. Could not duplicate problem after initial opening."

Detail Primary Flight Type: SCHEDULED AIR CARRIER

Secondary Flight Type: PASSENGERS

Type of Operation: AIR CARRIER/COMMERCIAL

Registration Number: 854TW

Total Aboard: 98

Fatalities: 0

Injuries: 0 Landing Gear:

Aircraft Weight Class: OVER 12500 LBS

Engine Make:

Engine Model:

Engine Group:

Number of Engines: 3

Engine Type:

Environmental/Operations Information Primary Flight Conditions: UNKNOWN

Secondary Flight Conditions: WEATHER NOT A FACTOR

Wind Direction (deg):

Wind Speed (mph):

Visibility (mi):

Visibility Restrictions:

Light Condition: DAY

Flight Plan Filed: INSTRUMENT FLIGHT RULES

Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT

Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND

Pilot Qualification: QUALIFIED Flight Time (Hours) Total Hours:

Total in Make/Model: 0

Total Last 90 Days: 0

Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

General Information

Data Source: FAA INCIDENT DATA SYSTEM
 Report Number: 19861208079879C
 Local Date: 12/08/1986
 Local Time: 08:45
 City: MEMPHIS
 State: TN

Airport Name:
 Airport Id:
 Event Type: INCIDENT - AIR CARRIER
 Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
 Phase of Flight: CLIMB TO CRUISE
 Aircraft Make/Model: BOEING B-727-223
 Airframe Hours: 33354
 Operator Code: AALA
 Operator: AMERICAN AIRLINES INC - AALA
 Owner Name: AMERICAN AIRLINES INC

Narrative

UNABLE TO CONTROL CABIN PRESSURIZATION IN AUTO OR MANUAL MODE.
 FOUND
 CARGO DOOR SEAL OUT OF THE TRACK.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
 Secondary Flight Type: PASSENGERS
 Type of Operation: AIR CARRIER/COMMERCIAL
 Registration Number: 847AA
 Total Aboard: 74
 Fatalities: 0
 Injuries: 0 Landing Gear:
 Aircraft Weight Class: OVER 12500 LBS
 Engine Make:
 Engine Model:
 Engine Group:
 Number of Engines: 3
 Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
 Secondary Flight Conditions: WEATHER NOT A FACTOR
 Wind Direction (deg):
 Wind Speed (mph):
 Visibility (mi):
 Visibility Restrictions:
 Light Condition: DAY
 Flight Plan Filed: UNKNOWN
 Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
 Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
 Pilot Qualification: QUALIFIED Flight Time (Hours) Total Hours:
 Total in Make/Model: 0
 Total Last 90 Days: 0
 Total Last 90 Days Make/Model: 0 FAA INCIDENT DATA SYSTEM REPORT

General Information

Data Source: FAA INCIDENT DATA SYSTEM
 Report Number: 19861227081709C
 Local Date: 12/27/1986
 Local Time: 09:11
 City: CHICAGO
 State: IL
 Airport Name: CHICAGO O'HARE INTL
 Airport Id: ORD
 Event Type: INCIDENT - AIR CARRIER
 Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
 Phase of Flight: CLIMB TO CRUISE
 Aircraft Make/Model: DOUG DC-8-73F
 Airframe Hours:
 Operator Code: TAGA
 Operator: ORION LIFT SERVICE INC - TAGA
 Owner Name: ORION AIR INC

Narrative

CARGO DOOR OPENED ON TAKEOFF. RETURNED WITH DOOR LIGHTS ON.

Detail

Primary Flight Type: ALL CARGO CARRIERS
 Secondary Flight Type: CARGO
 Type of Operation: AIR CARRIER/COMMERCIAL
 Registration Number: 808UP
 Total Aboard: 0
 Fatalities: 0
 Injuries: 0 Landing Gear: RETRACT TRICYCLE
 Aircraft Weight Class: OVER 12500 LBS
 Engine Make:
 Engine Model:
 Engine Group:
 Number of Engines: 4
 Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
 Secondary Flight Conditions: WEATHER NOT A FACTOR
 Wind Direction (deg):

Wind Speed (mph):
 Visibility (mi):
 Visibility Restrictions:
 Light Condition: DAY
 Flight Plan Filed: INSTRUMENT FLIGHT RULES
 Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
 Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
 Pilot Qualification: QUALIFIED Flight Time (Hours) Total Hours:
 Total in Make/Model: 0
 Total Last 90 Days: 0
 Total Last 90 Days Make/Model: 0
 FAA INCIDENT DATA SYSTEM REPORT

General Information

Data Source: FAA INCIDENT DATA SYSTEM
 Report Number: 19870408025949C
 Local Date: 04/08/1987
 Local Time: 07:08
 City: GREAT FALLS
 State: MT
 Airport Name: GREAT FALLS INTL
 Airport Id: GTF
 Event Type: INCIDENT - AIR CARRIER
 Mid Air Collision: NOT A MIDAIR
 Aircraft Information
 Aircraft Damage: NONE
 Phase of Flight: CLIMB TO CRUISE
 Aircraft Make/Model: BOEING B-737-222
 Airframe Hours:
 Operator Code: UALA
 Operator: UNITED AIR LINES INC - UALA
 Owner Name: UNITED AIRLINES INC

Narrative

A CARGO DOOR WARNING LIGHT CAME ON DURING CLIMB. THE AIRCRAFT
 RETURNED
 TO THE AIRPORT. DOOR IMPROPERLY LATCHED.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
 Secondary Flight Type: PASSENGERS AND CARGO
 Type of Operation: AIR CARRIER/COMMERCIAL
 Registration Number: 9051U
 Total Aboard: 39
 Fatalities: 0
 Injuries: 0 Landing Gear:
 Aircraft Weight Class: OVER 12500 LBS

Engine Make:
 Engine Model:
 Engine Group:
 Number of Engines: 2
 Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
 Secondary Flight Conditions: WEATHER NOT A FACTOR
 Wind Direction (deg):
 Wind Speed (mph):
 Visibility (mi):
 Visibility Restrictions:
 Light Condition: DAY
 Flight Plan Filed: INSTRUMENT FLIGHT RULES
 Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
 Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
 Pilot Qualification: QUALIFIED Flight Time (Hours) Total Hours:
 Total in Make/Model: 0
 Total Last 90 Days: 0
 Total Last 90 Days Make/Model: 0 FAA INCIDENT DATA SYSTEM REPORT

General Information

Data Source: FAA INCIDENT DATA SYSTEM
 Report Number: 19870430022259C
 Local Date: 04/30/1987
 Local Time: 07:45
 City: COLUMBUS
 State: OH
 Airport Name: PORT COLUMBUS INTL
 Airport Id: CMH
 Event Type: INCIDENT - AIR CARRIER
 Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
 Phase of Flight: TO INITIAL CLIMB (1ST POWER REDUCTION)
 Aircraft Make/Model: BOEING B-737-204
 Airframe Hours:
 Operator Code: PDLA
 Operator: PRESIDENTIAL AIRWAYS INC - PDLA
 Owner Name: PRESIDENTIAL AIRWAYS INC

Narrative

THE AIRCRAFT WOULD NOT PRESSURIZE AND THE AIRCRAFT RETURNED TO AIRPORT.
 CARGO DOOR UNLATCHED. WARNING LIGHT
 IN OP.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
 Secondary Flight Type: PASSENGERS
 Type of Operation: AIR CARRIER/COMMERCIAL
 Registration Number: 313XV
 Total Aboard: 31
 Fatalities: 0
 Injuries: 0 Landing Gear:
 Aircraft Weight Class: OVER 12500 LBS
 Engine Make:
 Engine Model:
 Engine Group:
 Number of Engines: 2
 Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
 Secondary Flight Conditions: WEATHER NOT A FACTOR
 Wind Direction (deg):
 Wind Speed (mph):
 Visibility (mi):
 Visibility Restrictions:
 Light Condition: DAY
 Flight Plan Filed: INSTRUMENT FLIGHT RULES
 Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
 Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
 Pilot Qualification: QUALIFIED Flight Time (Hours) Total Hours: 8400
 Total in Make/Model: 830
 Total Last 90 Days: 160
 Total Last 90 Days Make/Model: 160
 -

FAA INCIDENT DATA SYSTEM REPORT

General Information

Data Source: FAA INCIDENT DATA SYSTEM
 Report Number: 19870310025169C
 Local Date: 03/10/1987
 Local Time: 10:25
 City: LONDON, UNITED KINGDOM
 State: OF
 Airport Name:
 Airport Id:
 Event Type: INCIDENT - AIR CARRIER
 Mid Air Collision: NOT A MIDAIR
 Aircraft Information

Aircraft Damage: NONE
 Phase of Flight: CLIMB TO CRUISE
 Aircraft Make/Model: BOEING B-747-121
 Airframe Hours: 68950
 Operator Code: PAAA
 Operator: PAN AMERICAN WORLD AIRWAYS INC - PAAA
 Owner Name: PAN AMERICAN WORLD AIRWAYS INC

Narrative

THE AIRCRAFT RETURNED TO AIRPORT WHEN UNABLE TO PRESSURIZE THE CABIN.

WORN. CARGO DOOR LATCH TORQUE TUBE

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
 Secondary Flight Type: PASSENGERS
 Type of Operation: AIR CARRIER/COMMERCIAL
 Registration Number: 740PA
 Total Aboard: 245
 Fatalities: 0
 Injuries: 0 Landing Gear:
 Aircraft Weight Class: OVER 12500 LBS
 Engine Make:
 Engine Model:
 Engine Group:
 Number of Engines: 4
 Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
 Secondary Flight Conditions: WEATHER NOT A FACTOR
 Wind Direction (deg):
 Wind Speed (mph):
 Visibility (mi):
 Visibility Restrictions:
 Light Condition: DAY
 Flight Plan Filed: INSTRUMENT FLIGHT RULES
 Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
 Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
 Pilot Qualification: QUALIFIED Flight Time (Hours) Total Hours:
 Total in Make/Model: 0
 Total Last 90 Days: 0
 Total Last 90 Days Make/Model: 0 FAA INCIDENT DATA SYSTEM REPORT

General Information

Data Source: FAA INCIDENT DATA SYSTEM

Report Number: 19841101064029C
 Local Date: 11/01/1984
 Local Time: 20:43
 City: DETROIT
 State: MI
 Airport Name: SVM
 Airport Id: SVM
 Event Type: INCIDENT - AIR CARRIER
 Mid Air Collision: NOT A MIDAIR
 Aircraft Information
 Aircraft Damage: NONE
 Phase of Flight: NORMAL CRUISE
 Aircraft Make/Model: LKHEED L-188-A
 Airframe Hours: 40607
 Operator Code: ZIAA
 Operator: ZANTOP INTERNATIONAL AIRLINES INC - ZIAA
 Owner Name: ZANTOP INTERNATIONAL AIRLINES

Narrative

CREW DOOR PORTION OF FORWARD CARGO DOOR SEPARATED DROM AIRCRAFT
 OVER LAKE ERIE. RETURNED FOR LANDING.

Detail

Primary Flight Type: ALL CARGO CARRIERS
 Secondary Flight Type: CARGO
 Type of Operation: AIR CARRIER/COMMERCIAL
 Registration Number: 346HA
 Total Aboard: 0
 Fatalities: 0
 Injuries: 0 Landing Gear:
 Aircraft Weight Class: OVER 12500 LBS
 Engine Make:
 Engine Model:
 Engine Group:
 Number of Engines: 4
 Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
 Secondary Flight Conditions: WEATHER NOT A FACTOR
 Wind Direction (deg):
 Wind Speed (mph):
 Visibility (mi):
 Visibility Restrictions:
 Light Condition: NIGHT
 Flight Plan Filed: INSTRUMENT FLIGHT RULES
 Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
 Pilot Rating: AIRPLANE MULTI-ENGINE LAND
 Pilot Qualification: QUALIFIED Flight Time (Hours) Total Hours:
 Total in Make/Model: 0
 Total Last 90 Days: 0
 Total Last 90 Days Make/Model: 0 FAA INCIDENT DATA SYSTEM REPORT

General Information

Data Source: FAA INCIDENT DATA SYSTEM
 Report Number: 19860128014289C
 Local Date: 01/28/1986
 Local Time: 10:13
 City: ST LOUIS
 State: MO
 Airport Name: LAMBERT-ST LOUIS INTL
 Airport Id: STL
 Event Type: INCIDENT - AIR CARRIER
 Mid Air Collision: NOT A MIDAIR
 Aircraft Information
 Aircraft Damage: NONE
 Phase of Flight: TO INITIAL CLIMB (1ST POWER REDUCTION)
 Aircraft Make/Model: CVAC CV-340-XXX
 Airframe Hours:
 Operator Code: GAIA
 Operator: KITTY HAWK AIRCARGO INC - GAIA
 Owner Name: GENERAL AVIATION INC

Narrative

FORWARD CARGO DOOR OPENED AS AIRCRAFT TOOK OFF. OBJECTS DROPPED
 OUT.
 RETURNED. FAILED TO SEE WARNING LIGHT.

Detail

Primary Flight Type: ALL CARGO CARRIERS
 Secondary Flight Type: CARGO
 Type of Operation: AIR CARRIER/COMMERCIAL
 Registration Number: 453GA
 Total Aboard: 0
 Fatalities: 0
 Injuries: 0 Landing Gear:
 Aircraft Weight Class: OVER 12500 LBS
 Engine Make:
 Engine Model:
 Engine Group:
 Number of Engines: 2
 Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN

Secondary Flight Conditions: WEATHER NOT A FACTOR
 Wind Direction (deg):
 Wind Speed (mph):
 Visibility (mi):
 Visibility Restrictions:
 Light Condition: DAY
 Flight Plan Filed: INSTRUMENT FLIGHT RULES
 Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
 Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
 Pilot Qualification: QUALIFIED Flight Time (Hours) Total Hours: 6000
 Total in Make/Model: 500
 Total Last 90 Days: 0
 Total Last 90 Days Make/Model: 0

<<>>

FAA INCIDENT DATA SYSTEM REPORT

General Information

Data Source: FAA INCIDENT DATA SYSTEM
 Report Number: 19831229069289C
 Local Date: 12/29/1983
 Local Time: 22:15
 City: CHICAGO
 State: IL
 Airport Name: CHICAGO O'HARE INTL
 Airport Id: ORD
 Event Type: INCIDENT - AIR CARRIER
 Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
 Phase of Flight: CLIMB TO CRUISE
 Aircraft Make/Model: BOEING B-747-131
 Airframe Hours:
 Operator Code: TWAA
 Operator: TRANS WORLD AIRLINES INC - TWAA
 Owner Name: TRANS WORLD AIRLINES INC

Narrative

AFT CARGO DOOR LIGHT ILLUMINATED ON CLIMBOUT. DOOR DIFFERENTIAL
 FLAPPER

DOOR OPEN DUE TO ICED UP MASTER LOCK PIN.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
 Secondary Flight Type: PASSENGERS AND CARGO
 Type of Operation: AIR CARRIER/COMMERCIAL

Registration Number: 93108
 Total Aboard: 0
 Fatalities: 0
 Injuries: 0 Landing Gear:
 Aircraft Weight Class: OVER 12500 LBS
 Engine Make:
 Engine Model:
 Engine Group:
 Number of Engines: 4
 Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
 Secondary Flight Conditions: FREEZING TEMPERATURE
 Wind Direction (deg):
 Wind Speed (mph):
 Visibility (mi):
 Visibility Restrictions:
 Light Condition: NIGHT
 Flight Plan Filed: INSTRUMENT FLIGHT RULES
 Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
 Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
 Pilot Qualification: QUALIFIED Flight Time (Hours) Total Hours:
 Total in Make/Model: 0
 Total Last 90 Days: 0
 Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

General Information

Data Source: FAA INCIDENT DATA SYSTEM
 Report Number: 19840214010999C
 Local Date: 02/14/1984
 Local Time: 06:45
 City: JAMAICA
 State: NY
 Airport Name: JOHN F KENNEDY INTL
 Airport Id: JFK
 Event Type: INCIDENT - AIR CARRIER
 Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
 Phase of Flight: FINAL APPROACH- INSTRUMENT FLIGHT RULES
 Aircraft Make/Model: DOUG DC-8-63F
 Airframe Hours:
 Operator Code:
 Operator:
 Owner Name: VIASA VENEZUELA

Narrative

FORWARD CARGO DOOR OPENED ON FINAL APPROACH. CAUSE OF THE DOOR OPENING
 COULD NOT BE DETERMINED.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
 Secondary Flight Type: CARGO
 Type of Operation: FOREIGN AIR CARRIER
 Registration Number: 801WA
 Total Aboard: 0
 Fatalities: 0
 Injuries: 0 Landing Gear:
 Aircraft Weight Class: OVER 12500 LBS
 Engine Make:
 Engine Model:
 Engine Group:
 Number of Engines: 4
 Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
 Secondary Flight Conditions: WEATHER NOT A FACTOR
 Wind Direction (deg):
 Wind Speed (mph):
 Visibility (mi):
 Visibility Restrictions:
 Light Condition: DAWN
 Flight Plan Filed: NONE
 Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
 Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
 Pilot Qualification: QUALIFIED Flight Time (Hours) Total Hours:
 Total in Make/Model: 0
 Total Last 90 Days: 0
 Total Last 90 Days Make/Model: 0

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FAA INCIDENT DATA SYSTEM REPORT

General Information

Data Source: FAA INCIDENT DATA SYSTEM
 Report Number: 19840310022409C
 Local Date: 03/10/1984
 Local Time: 13:41
 City: DALLAS
 State: TX
 Airport Name: DALLAS/FORT WORTH INTERNATIONAL
 Airport Id: DFW

Event Type: INCIDENT - AIR CARRIER
 Mid Air Collision: NOT A MIDAIR
 Aircraft Information
 Aircraft Damage: MINOR
 Phase of Flight: NORMAL CRUISE
 Aircraft Make/Model: BOEING B-727-123
 Airframe Hours: 50208
 Operator Code: AALA
 Operator: AMERICAN AIRLINES INC - AALA
 Owner Name: AMERICAN AIRLINES INC

Narrative

RAPID DECOMPRESSION AT CRUISE ALTITUDE. FOUND FATIGUE FAILURE OF THE
 FUSELAGE SKIN FORWARD OF THE AFT CARGO
 D O O R .

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
 Secondary Flight Type: PASSENGERS AND CARGO
 Type of Operation: AIR CARRIER/COMMERCIAL
 Registration Number: 1993
 Total Aboard: 38
 Fatalities: 0
 Injuries: 0 Landing Gear:
 Aircraft Weight Class: OVER 12500 LBS
 Engine Make:
 Engine Model:
 Engine Group:
 Number of Engines: 3
 Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
 Secondary Flight Conditions: WEATHER NOT A FACTOR
 Wind Direction (deg): 03
 Wind Speed (mph): 06
 Visibility (mi): GREATER THAN 10 MILES
 Visibility Restrictions:
 Light Condition: DAY
 Flight Plan Filed: INSTRUMENT FLIGHT RULES
 Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
 Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
 Pilot Qualification: QUALIFIED Flight Time (Hours) Total Hours:
 Total in Make/Model: 0
 Total Last 90 Days: 0
 Total Last 90 Days Make/Model: 0

**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

Appendix G: Wiring

NTSB AAR 00/03:

1.18.2 Information Regarding Electrical/Wiring Anomalies on
Airplanes

1.18.2.1 Accidents, Incidents, and Events Involving Electrical/Wiring
Components

During its investigation of the TWA flight 800 accident, the Safety Board examined its aviation accident/incident database for records of previous accidents and incidents involving transport-category airplanes in which the Board had used the words wire or wiring in the probable cause. In addition, the Safety Board reviewed other available records involving wiring- and/or fire/smoke-related air carrier events, including the following:

- Boeing laboratory reports, SBs, and SLs;
- AFRL reports;
- Safety Board preliminary, airworthiness factual, and accident brief reports;
- AIR 2000 air safety reports;
- British Air Accidents Investigation Branch (AAIB) reports;
- FAA service difficulty reports (SDR); 370 and
- a Civil Aviation Administration of China investigation report.

The results of these reviews are discussed in this section.

Wiring-Related Accidents/Incidents

In an October 21, 1996, fax, the Civil Aviation Authority of Singapore described an event that occurred on October 12, 1996, in which an operator reported that arcing in a wire bundle on a 747-200 cargo airplane had resulted in a fire at the aft bulkhead of the forward cargo compartment about STA 1000. The airplane was undergoing maintenance at the time of the fire, and subsequent inspection revealed damage to wire bundles W834, W846, W1524, and W370; the insulation blanket; the aft bulkhead of the forward cargo compartment; and (possibly) the CWT sealant. The operator removed the affected components from the airplane and shipped them to Boeing for examination and evaluation. A December 16, 1996, letter from Boeing stated that X-ray microanalysis and chemical identification of the damaged wire suggest that the insulation of the wire was damaged and that arcing had occurred between the damaged wires or that arcing between the damaged wires and ground had occurred.

From IASA: The International Aviation Safety Association is a non profit safety organization incorporated in New York.

Website at www.IASA.com.au .

Chairman: Mrs. Lyn Susan Romano

Description of High-Temperature Aircraft Electrical Wires. Only One, TKT MEETS FAA's FAR 25 STANDARDS. Sources; Industry Wire Experts. Contact jking1@mediaone.net

TypePropertiesSome Aircraft Used In

PVC/NYLON 592) 1979	<ul style="list-style-type: none"> *Heaviest and thickest at 6.8 lbs. per 1,000 ft. *Insulation burns readily creating <u>copious</u> smoke *Insulation turns to hydraulic acid when exposed to water. 	Early DC-9s (e.g., ValuJet 727s, 737s until
Poly-X (Aliphatic Polyimide)	<ul style="list-style-type: none"> *The first exotic blend of insulation (due to oil embargo) *Light weight, 4.7 lbs. per 1,000 ft. *Susceptible to solvents *Chafing resistant but cracks around Circumference *Copious smoke *Due to brittleness, 1" bare spots not uncommon * premature aging at just 4,000 hrs * Fails FAR 25 	Early 747s (e.g., TWA 800) and DC-10s
XL Tefzel (Spec 55) * Arc tracks * Soft as butter at rated 150 degrees C – not 200 C	<ul style="list-style-type: none"> * Copious smoke, density greater than 96% * Cracks easiest under vibration (ETEF Type) * Toxicity the worst (ETE Type) * Explodes in oxygen enriched areas * Fails FAR 25 	747s, 767s, 777s years?
Stilan 10s built 1970s * Fails FAR 25	<ul style="list-style-type: none"> *Light weight, 4.7 lbs. per 1,000 ft. *Insulation breaks down in hydraulic and de-icing fluid *Microscopic crazing problem seen by microscope *Cracks under stress *Found to arc over * Spurious signal generation 	747s and DC- in mid-to-late
Kapton some 747s (Aromatic 400s) 767s, DC-10s Polyimide and	<ul style="list-style-type: none"> *Very light weight, 4.5 lbs per 1,000 ft *Insulation burns fiercely creating <u>no</u> smoke *Known to arc over * Burns fiercely with arc over * Fails FAR 25 	727s, 737s, (MD-80, MD-11, A300-600 (with teflon top coat)
TKT built o n	<ul style="list-style-type: none"> *Light weight, 5.0 lbs. in per 1,000 ft. *Abrasion resistant 	737s and 757s late 1992 and

- *Superb insulation protection
- *High heat tolerance
- *Resists smoking when burning (less than 2% density)
- *Used on some aircraft since 1992.

FAR 25 states: that insulation material can not be used that is hazardous, unreliable, or contributes smoke/fire. No particular uses of insulation were further specified so insulation material includes; seat insulation, insulation blankets, rug insulation, and wire insulation. They are all types of insulation materials. Unless they are tested with an electrical fire (2,000 degrees) igniter to prove flammability proof, the material can not meet far 25 requirements. By their own (Limited) standards, the FAA has said, in fact, that most types of wire can not be used ! Only TKT wire insulation meets FAR 25 Standards.

IASA STUDY OF 270 WIRE RELATED ACCIDENTS/INCIDENTS

LAST REVISED. 3/2/2001 by jking1@mediaone.net. IASA Data

Specialist

Introduction

The following is a chronological list and brief summaries to aircraft “Wire” related events including significant systems failures, smoke and or fires. Some industry actions have also been added. This list is by no means intended to represent all such events known but rather is an attempt to focus more clearly on those where wire or wire types become known. Other IASA studies are available that broaden these number of events where “electrical” becomes the focus rather than just those where the word “wire” is more easily recognized. 109 additional such items to the 270 here may be found on page 14.

Identifying the various wire types or that the wires themselves have become directly causal is difficult because of the absence of such fault coding in the ATA coding system used throughout the commercial industry. The industry has now recognized this diminishing factor and recognized by the military some years ago.

Sources

The vast majority of events seen here come from the databases of the FAA’s Office Of System Safety which include;

The FAA Incident Data Reporting System
 Aviation Safety Reporting System (ASRS)
 NTSB Accident/Incident Reports
 NTSB Recommendation Reports
 NTSB Monthly Reports
 And miscellaneous FAA Tech Reports/Letters

The URL source references and a guild to access them may be found at the back of this report. Also many other source URLs have been incorporated into the event description where economy of space allowed.

1. August 18, 1972 Lockheed L-1011. First recorded arc-tracking/arc-over event in commercial aircraft. 7 wires severed. Lockheed Report # 10 1973.
2. 6/30/77. TWA (W.B. Clark) objects to Boeing’s continued use of Kapton wiring.

- 3.5/27/83. L-1011, TWA. Flight 111, Smoke and flames in the cockpit. Kapton wire damage. NTSB Accident/Incident Report # MKC83IA116.
- 4 6/2/83. DC-9-32. Air Canada. Near Cincinnati experienced an inflight fire and an Emergency landing at Cincinnati. Lav pumps, associated wiring and deterioration of wire insulation were inspected. NTSB Monthly Report # DCA83AA028.
5. 9/2/83. TWA acknowledges over 30 instances with Kapton wiring failures. Report 1702.
- 6 5/17/84. DC-10, Northwest Airlines. During climb saw sparks and smoke from the left side panel under his glare shield. Flight returned, and wire-bundle insulation and fabric sleeve around wire-bundle were found burned. Circuit breakers were tested, no cause found as to why they failed to open. NTSB Accident/Incident Report # CHI84IA196
- 7.4/6/84. FAA acknowledges considerable adverse experience with Kapton wiring among several operators, stating an investigation is warranted. States problem is under-reported. Memorandum FAA's Leroy Keith to all managers of ACOs.
8. 1/14/85. 757, Monarch Airlines. Loss of left generator due to flashover of Kapton feeder cables and lavatory leak. See 1/26/89 FAA/ Congressman Dingell letter and AD 85-12-08.
9. 5/10/85. Monarch Airlines 757. Kapton power feeders chafe and arc. Wire-bundle vaporized. Adjacent wire-bundles damaged. Boeing Alert Service Bulletin 757-24A0025.
10. 9/19/85. 727, Braniff Airlines. On landing noticed sparks from C/B Panel. Replaced wires, C/Bs, current sensing coils. FAA Incident Rpt # 19850919051729C.
- 11.10/18/85. L-1011, Royal Jordanian Airlines in-flight fire. Kapton wires arced and ignited a titanium air-duct. NTSB Recommendations Rpt # A-85-91.
- 13.7/12/87. Delta 767-232, Kapton wiring harness causes uncommanded go-around malfunction. NTSB Monthly, Ref <http://www.nts.gov/aviation/NYC/87A202.htm>.
- 14.3/88. DC-10, Northwest Airlines. Fire in electrical compartment, arcing cables, flames 1 to 2 feet high from ignited insulation blankets. Ref. DOT/FAA/CT-91/2 TechRpt.
15. 2/24/89. 747, United flight 811. Faulty Wiring and/or switch cause door to open in-flight. Nine passengers lost. NTSB Rpt. # AAR-92/02. (superceded Rpt. # 90/01).
- 16.12/30/89. 737, America West. Fire in wheel well due to arcing wire against a hydraulic line. All hydraulics lost. Overran runway. NTSB Monthly Rpt. # LAX90FA061.
- 17.1/18/90. MD-80, U.S. Air. Overheated wire insulation filled cockpit with smoke. Loose generator terminals found, no cause to cockpit smoke. Ref. DOT/FAA/CT-TN94/55.
18. 5/11/90. 737, Phillipine Airlines. Shortly after pushback aircraft exploded. 8 dead. Wiring caused explosion of center fuel tank. Ref. NTSB Rpt A-90-103. http://www.asy.faa.gov/asp/asy_searchus.asp Type in "A-90-103"
- 3/17/91. L-1011, Delta Airlines. Flames from the base of the cabin sidewall. Wires burned, 5 C/Bs tripped. Diverted to Goose Bay, Canada. Ref. DOT/FAA/CT-TN94/55.
- 8/2/91. 737, U.S. Air. While at cruise, lavatory smoke detectors activated and crew smelled smoke but stopped when C/Bs were pulled. FAA Incident # 199108020441799C.
- 9/28/91. MD-82, Continental Airlines. While taxing smoke came out of the instrument panel. Emergency evac. NTSB Monthly Rpt. # NYC91LA247 and ASRS Rpt. 190436.
- 9/11. ASRS Pilot Report (de-identified). Cabin reported light bulb pop and cabin crew saw smoke. Electrical fire behind light panel. Flight diverted. ASRS Rpt. # 190451.
- 10/91. ASRS Pilot Report (de-identified). On climb out smoke reported in cabin. Returned and fire department called. ASRS Rpt. # 190756.
- 11/13/91. DC-8, Flagship Express. Cargo door opened in flight. Damaged wires found in a wire-bundle. NTSB Accident/Incident Rpt. # NYC92IA030.
- 12/91. ASRS PILOT Report (de-identified). On climb-out attendant reported smoke in the cabin. Returned flight. ASRS Rpt. 197455.
- 2/12/91. Evergreen 747-100 experiences in-flight upset and lost 10,000 ft approaching supersonic speeds. Spurious signals caused uncommanded inputs to the autopilot. Poly-X wiring known for spurious signal generation to autopilots. Ref. TSB Report and NTSB Log # 2359, 4/30/92.

1/3/92. 737, United Airlines. Noticed electrical burning odor. Loud arc then heard with flames from aft cockpit panel. Short in a large wire-bundle. NTSB Rpt. # DEN92IA025.

3/92. ASRS Pilot Report. Smoke in cabin and return to gate. During next flight smoke re-occurred. Emergency return. This was the 5 th time in one month. ASRS Rpt. # 206023.

6/20/92. DC-8, Hawaiian Airlines. On ground, smoke from C/B Panel with spiking fire. Used fire extinguisher. FAA Incident Rpt. # 19920620024179C.

6/92. ASRS Pilot Report (de-identified). Cabin declared a fire odor and ceiling was hot. Diverted and declared a emergency. ASRS Rpt. # 214032.

7/22/92. 727, Northwest Airlines. Smoke in the cockpit, diverted to Fort Wayne. Found burned wiring above co-pilots upper window. FAA Incident Rpt.# 19920722033979C.

7/92. ASRS Pilot Report (de-identified). Crew noted sparks, arcing and smoke half way back left side. C/B popped, fire stopped. FAA made 2 inquires. ASRS Rpt. # 214781.

9/92.ASRS Pilot Report (de-identified). At gate, smoke became thicker from behind attendant jump seat with power off. Fire dept called. ASRS Rpt. # 220716.

1/93. ASRS Pilot Report (de-identified). While descending smoke came from C/B Panel behind captain. Emergency divert to BFL, evacuation on runway. ASRS Rpt. # 231385.

5/10/93. MD-11F. # 3 Engine surges with autopilot on or off because of broken wire. Unscheduled landing. Ref FAA SDR 1993051700120. (item 3).

8/6/93. MD-11F. Precautionary shutdown # 2 engine. Replaced # 2 engine wiring cable. Cable assy failed. Ref FAA SDR 1993081100261. (item 4).

9/93. ASRS Pilot Report (de-identified). At post flight, smoke in the cabin. Emergency evacuation. Claimed FAA follow-up-(Incident Data not found). ASRS Rpt.# 251342.

10/8/93. MD-11. Lost ground spoilers. During inspection found numerous burned and chafed wires in the fwd avionics bay. Ref FAA SDR 1993111000022. (item 5).

10/16/93. MD-81, Swissair. Heavy smoke from overhead panel after departing Munich. Emergency landing. Ref. NTSB Recommendation Rpts A-94-136 & A-94-133. German Investigations Unit identified a faulty Emergency Power switch.

11/2/93. MD-11. FADEC fault, return to Block. Suspect “spurious digital signal”. Unable to duplicate. Ref FAA SDR 1993121300179. (item 6).

11/4/93. MD-87, Scandinavian Airlines. On landing crew noticed smoke in aft end. At the gate a fire erupted and extensively damaged the aircraft as arcing Kapton wires ignited flammable Mylar insulation blankets. Danish AAIB Rep # 2/96, SE-DIB.

4/11/94. A-320, Northwest Airlines. From cruise electrical wire insulation burning smell in cockpit. Diverted to Buffalo, replaced fan. FAA Incident Rpt. # 19940411012399C.

11/10/94. 737, China Airlines. After landing ground crew detected burning smell. Opened E/E bay and noted insulation blanket on fire under rack 2. Improper clamping allowed arcing Kapton wires to ignite flammable insulation blankets. Ref. FAA DOT/FAA/AR-97/58. Also see CAAC letter(7/24/96) to the FAA.

10/94. ASRS Pilot Report (de-identified). During cruise C/B Panel (P-18) behind captain emitted heavy smoke. C/B popped, smoke stopped. Emergency, diverted. ASRS #285007.

11/94 ASRS Pilot Report (de-identified). Departed LAX, aft cabin filled with smoke. Declared emergency, diverted. Met by FAA.. ASRS Rpt. # 288297.

11/94. ASRS Pilot report (de-identified). MD-80 aborted TO at O’Hare due to smoke/fumes in the cockpit and cabin.

12/8/94. Boeing 767 operator reports worn Kapton wires causing loss of passenger oxygen deployment, emergency lights, passenger signs, emergency evacuation signal and the fuel shutoff for the engine fire-handle switch. Ref. Boeing SB 767-35A0029.

1/8/95. MD-11F. Gear warning on climb out. Unscheduled landing. Found bad wire insulation to position indicator. Ref FAA SDR 1995011300722. (item 9).

1/11/95. DC-9, Columbian aircraft impacted the sea. 52 lost. Sparks and fire seen. Was first delayed because of electrical work. NTSB Monthly Rpt. # DCA95RA013.

50. 2/19/95. MD-11. Found galley power feeder wires arcing to L-3 door stop. (AD 98-25-11 addressed this 34 months later Ref FAA SDR 1995022400481. (item 11).
- 4/28/95. DC-10. Auto-pilot pitching violently, other deferred. Unscheduled landing. Same AGAIN on 4/29. Found shorts via pins 38-39 and for left outboard elevator. Ref FAA SDRs 1995060200120 and 1995060200121. (items 6 & 7).
- 4/29/95. MD-11. # 1 AC Buss Tie lock out, Return to gate. Wire # 3-16BL shorted to ground. Ref FAA SDR 19950551900452. (item 12).
- 5/95. ASRS Pilot Report (de-identified). Smoke in the cabin. Procedures did not stop smoke. Failure of Flap Indication and thrust reversers. FAA met A/C. ASRS # 305701.
- 5/10/95. 767. During layover found smoke in forward cabin from three shorted wires inside seat track 1C, 2C. Ref FAA SDR 1995051900313. (item 8).
- 5/17/95. 767. Lost right generator, unable to start APU. Unscheduled landing. Found short in IDG feeder. Ref FAA SDR 1995051900507. (item 10).
- 5/19/95. DC-10. C/Bs popped, lost # 1 and 2 generators. Unscheduled landing. Found burnt out wire-bundle in forward cargo ceiling. Ref FAA SDR 1995072100418. (item 9).
- 7/7/95. MD-11. Inspection found arcing and burning off of the pins in the automatic control PCU located in the recess of the Tail Fuel Tank. Concern is the proximity of this Fuel tank. Suspect faulty materials/ sealing. Ref FAA SDR 1995080400534. (item 13).
- 8/18/95. 767. During cruise found wire-bundle arcing along sidewall, seats 2A & 3A. Activated a fire extinguisher. Ref FAA SDR 1995082500003. (item 20).
- 8/6/95. MD-11, China Airlines. At gate, smoke came from E&E bay. Arcing Kapton wires ignited flammable Mylar batts. Ref. DOT/FAA/AR-97/58 & CAAC /FAA letter.
- 9/8/95. DC-10. A false warning to high engine oil temperature with engine shutdown and unscheduled landing. A bad wire to ground was found. Ref FAA SDR 1995091500033.
- 9/95. ASRS Pilot Report (de-identified). During cruise heavy smoke in the cabin. Emergency divert to Nassau. Claimed FAA Investigation. None found. ASRS # 315585.
- 11/2/95. MD-11. Found on Inspection two engine wire-harnesses chafed. Two incidents; this one -- Ref FAA SDR 1995111300460 And 1995111300461 on 11/6. (items 15,16)
- 11/13/95. 737, China Airlines. Mylar Insulation blankets set afire by hot drill chips from maintenance. Ref. DOT/FAA/AR-97/58 and CAAC / FAA Letter 7/24/96 (as above).
- 11/26/95. MD-82, Atitalia. Prior to TO, fire in the cabin from light ballast spread quickly through ceiling panels, wire-harnesses, insulation blankets. Ref. DOT/FAA/AR-97/58.
- 11/95. ASRS Pilot Report (de-identified). 737 on taxi-out saw smoke in the cockpit from generator control panel. Third event. FO required medical help. ASRS Rpt. # 321583.
- 11/95. ASRS Pilot Report (de-identified). MD-88 cabin advised of smoke alarm and odor in the cabin. Smoke in the cockpit. Returned to Atlanta. Cause unknown. ASRS 322428.
- 11/95. ASRS Pilot Report (de-identified). DC-10 recurring electrical fuel pump failures during fuel dump. Noticed hot electrical smell. Flight returned. ASRS Rpt. # 320312.
- 1/11/96. MD-11. During cruise had a # 1 engine generator warning. Found shorted and damaged feeder cables in the pylon. Ref FAA SDR 1996011200174. (item 19).
- 1996 the NTSB declares Air Force One, the President's aircraft, rewired due to concerns with Kapton wire. Ref. Center Public Integrity Rpt. "In The Unlikely Event", ISBN1882583-10-8.
- 1/16/96. 737. During inspection found chafed wire and arcing at E 3-2 Rack. Ref FAA SDR 1996012600172. (item 2).
- 2/25/96. DC-9. Aborted approach because could not get green gear light. Declared emergency. Faulty wire at switch. Ref FAA SDR 19960301000170. (item 10).
- 3/2/96. DC-9. A flash and smoke at row 5. Light disconnected due to chafed wires. Light okay. Ref FAA SDR 1996030800123. (item 13).
- 3/3/96. 737. During climb smoke came from the aft galley area. Unscheduled landing. Found shorted wire. Ref FAA SDR 1996052300102. (item 19).
- 3/8/96. 747. Leading edge warning during taxi. Found wiring shorted. Return to gate. Ref FAA

SDR 1996031500155. (item 4).

3/8/96. DC-9. Smoke while at the gate smoke from overhead near entry. Found burned wiring, scorched insulation. Ref FAA SDR 1996040500468. (item 22).

4/26/96. DC-10. In flight had smell of hot insulation by rows 14 to 18. Could not duplicate. Return to service. Ref FAA SDR 1996050200380. (item 21).

4/28/96. MD-11. Flight arrived with five Avionic C/Bs tripped. Found wire-bundle chafing. Ref FAA SDR 1996060600568. (item 25).

5/3/96. DC-9. At cruise fire annunciator and fire loop illuminated. Found wires W255A16 and 286A16N rubbing together. Ref FAA SDR 1996101000691. (item 41).

5/12/96. DC-9. No green gear light. Diverted to SYR. Replaced left down limit switch wire-harness. Ref FAA SDR 1996062000576. (item 31).

5/31/96. 747. On approach electrical burning smell in cockpit. Taxi light could not be turned off. Shorted witch and wire found. Ref FAA SDR 1996062700585. (item 15).

5/31/96. DC-9. During cruise, smoke in the aft cabin behind F/As seat. Found two burnt wires. Ref FAA SDR 1997010200195. (item 54).

6/1/96. 767. Inspection found numerous C/Bs tripped and chafed wires aft of CHILLER Unit in E/E compartment. Ref FAA SDR 1996061300112. (item 41).

6/5/96. DC-10. During takeoff had slat-disagree lights. Aborted TO. Found chafed wire and replaced sensor to prox box wires. Ref FAA SDR 1996061300092. (item 25).

6/12/96. 747. On climb out had flap lockout. Diverted flight. Found shorted wiring near P54 Panel. Ref FAA SDR 19960620001888. (item 11).

6/15/96. 747. During climb the red light for the nose gear “unsafe” came on. Repaired wire. Ref FAA SDR 1996062700006. (item 12).

6/17/96. DC-9. At the gate, had smoke in the cabin. Light ballast and charred wiring was replaced. Ref FAASDR 1996062000380. (item 30).

6/18/96. 737. On approach anti skid warning came on. Diverted to BWI. Replaced right main gear wire strut harness. Ref FAA SDR 1996071000673. (item 39).

6/23/96. 747. During climb the # 3 hydraulic overheat warning came on. Unscheduled landing. Repaired wire for indication problem. Ref FAA SDR 1996062700179. (item 13).

6/25/96. 767-332ER, Delta Airlines. Wires arced and severed one of two aileron cables. Lost right generator. Emergency landing. Ref. NTSB Monthly Rpt. NYC96IA131. SDR

7/21/96. DC-9. Inspection found the sidewall lights to be flickering. A wire burnt wire-harness was found. Ref FAA SDR 1996072500306. (item 36).

7/22/96. DC-9. Flight attendant reported no power to the forward coffeemaker. Inspection revealed melted wires to a terminal block. Ref FAA SDR 1996080200386. (item 38).

7/26/96. 747, TWA 800. High voltage Poly-X wiring outside the center fuel tank was bundled with the low voltage, split Teflon FQIS wiring inside the tank. A spark/arc transferred this energy into the tank through the wiring. Ref. NTSB AAR-00/03.

7/28/96. 767. During cruise wiring at seats 2A and others shorted and burned through. Ref FAA SDR 1996080200439. (item 52).

7/31/96. 737. Inspection found APU feeder harness and a stringer burnt. Ref FAA SDR 1996080800015. (item 43).

8/5/96. DC-9. At engine start smoke entered the cockpit. Burned wire found at the right heat-exchanger fan. Ref FAA SDR 1996080800520. (item 39).

8/13/96. 737. During cruise, left wing overheat light flickered. Unscheduled landing. Wire found chafed through and shorting. Ref FAA SDR. 1997013000457. (item 96).

8/31/96. 747. During taxi, primary display and C/B tripped. Returned to gate. Repaired chafed wire. Ref FAA SDR 19960905000421. (item 24).

9/3/96. 747. During cruise electrical arc and smoke came from galley work light. Found charred wiring insulation. Ref FAA SDR 1996092600668. (item 27).

10/7/96. 737. During cruise smoke came from behind cockpit overhead panel. Burnt wiring was

found. Ref FAA SDR 1996101700002. (item 63).

10/7/96. 737. During takeoff # 2 thrust reverser unlock light came on, aborted takeoff. Found chafed wire in pylon area. Ref FAA SDR 19961114000362. (item 72).

10/8/96. MD-11. Inspection found # 2 generator feeder cables chafed over right over wing exit. Ref FAA SDR 1996110100255. (item 28).

10/13/00. DC-9. Inspection found 24 lighting wires burnt, right side, station 1083 to 1205. Ref FAA SDR 1996101700537. (item 43).

11/4/96. DC-9. On approach, aft and forward fuel boost pumps C/Bs tripped. Found wire-bundle chafed in left wing. Ref FAA SDR 1996111400055. (item 47).

11/17/96. 737. Prior to takeoff, sparking, popping and smoke from compass and ignition switch area. Returned to gate. Saw chafed wire. Ref FAA SDR 199611200285. (item 74)

11/23/96. DC-9. During climb, burning odor in cabin. Unscheduled landing. Replaced damaged left ground power wire. Ref FAA SDR 1996121900609. (item 51).

12/10/96. 737. During inspection for ADI malfunction, lav water was found in wire-bundles feeding E/E compart connectors. Ref FAA SDR 1997032700535. (item 125)

12/11/96. 757, U.S. Air. Enroute, smoke and fire were visible in the aft floor and side wall area. Emergency and diverted. Examination of the burned area revealed an Audio-entertainment system cable had become shorted. Ref. NTSB Monthly Rpt. CHI97IA041.

12/14/96. 737. During inspection found left wing wire-bundle melted 15 of 32 wires. Ref Boeing service letter 737-SL-24-27. Ref FAA SDR 1996122600319. (item 82).

12/20/96. DC-10. At cruise, C/B for mid cabin reading lights popped. Reset, and burning smell began. Wiring found to be charred. Ref FAA SDR 1996122600432. (item 37).

12/20/96. 737. During climb # 1 engine surged. Declared an emergency and returned. Replaced engine PMC blue harness assembly. Ref FAA SDR 1997012300452. (item 93).

12/27/96. DC-9. After takeoff, right wing fuel boost pump C/B popped, then reset. Aft pump C/B popped, then forward again. Connector arcing, insulation damage in the fuel conduits was noted. Phase C/Bs popped. Ref FAA SDR 1997010200560. (item 55).

1/30/97. Several Boeing 767 Operators report loss of system failure(s) and/or fire due to Kapton wiring chafing on oxygen line fitting which could lead to electrical arcing. Boeing SB 767-35A00229, 6/25/98.

1/14/97. 737. During a inspection, fluid passing through a connector shorted out the rudder Power Control Unit solenoid. Ref FAA SDR 1997030600012. (item 114).

1/15/97. DC-10. During cruise, wing anti ice valves disagree light illuminated and then the # 3 manifold fail light. Found Wire-bundle burned. Ref FAA SDR 1997020600768.

1/20/97. 767. Inspection found strong electrical smell in aft galley. Unable to isolate. Suspect Chiller. Ref FAA SDR 1997013000095. (item 77).

1/20/97. DC-9, Northwest Airlines. Smoke from panel behind captain's seat. Charred wiring due to phase short and dust particles. NTSB Monthly Rpt. # CHI97IA072.

1/23/97. 767. Inspection found broken wire in cargo hold tripped a C/B. Resetting caused a small fire in the hold and in the insulation. Ref FAA SDR 1997122900005. (item 121).

1/27/97. 737. During cruise, lost series of systems including pressurization. Unable to reset C/Bs, Diverted. # 1 gen wire burnt. Ref FAA SDR 1997020600127. (item 105).

1/27/97. 737. On climb lost radar. Returned to gate. Found shorted Data A Buss B-wire. Ref FAA SDR 1997013000834. (item 104).

3/7/97. 737. While landing had flaps freeze. Found wire between connectors shorted to shield. Ref FAA SDR 1997032700165. (item).

3/8/97. 747. Inspection found # 1 APU generator feeder cables with split insulation and melted spacers. Ref FAA SDR 1997041700153. (item 44).

3/10/97. 737. In cruise, an uncommanded pressurization decent (manual). Unscheduled landing. Chafed wires near outflow valve. Ref FAA SDR 1997070300284. (item 171).

3/14/97. 737. Sparks under seat 9D. Found shorted wires. Ref FAA SDR 1997032700004. (item

121).

3/14/97. 747. Inspection found chafed wire-harness and a bare wire with signs of arcing at # 1 reserve tank and rib. Ref FAA SDR 1997040300806. (item 43).

3/30/97. DC-9. On climb had fault with right main gear unsafe light. Found high resistance of uplock to terminal wire. Ref FAA SDR 1999041000284. (item 61).

4/24/97. 747. Inspection found # 2 fuel boost pump wiring insulation failed due to conductive corrosion. Ref FAA SDR 1998011500139. (item 72).

4/28/97. 747-243, G-VIRGIN. Arcing Poly-X wires ignite cabin interior materials and destroy wire-bundles behind overhead panels in forward cabin. Ref, UK AAIB Rpt. # 5/2000 (EW/C98/1/3) Appendix G. (www.open.gov.uk/aaib/n653ua/n653ua.htm).

5/9/97. 737. Engine fire warning on touchdown. Fired extinguisher. Found badly chafed fire wire at a clamp. Ref FAA SDR 19970717000869. (item 174).

5/10/97. 737. While at cruise had # 1 transformer rectifier C/B tripping. Unscheduled landing. Found melted wires on C/B. Ref FAA SDR 1997052200816. (item 156).

5/24/97. DC-9. On approach, gear warning light would not go out. Found bare wires and water inside wire conduit. Ref FAA SDR 1997060500660. (item 63).

6/7/97. 737. Smoke and electrical smell near start switch., switch shorted to standby compass. Repaired five wires. Ref FAA SDR 1997 061900262. (item 163).

6/11/97. 747. Smoke and sparks at seat 2EF. Attendant used extinguisher. Repaired failed wiring. Ref FAA SDR 1998021100983. (item 76).

6/17/97. 737. On climb, engine EGT went to 1250 and then blank. Unscheduled landing. Found EGT wires shorted at engine harness. Ref FAA SDR 1997071000062. (item 172).

6/21/97. 767. At cruise had uncommanded IDG disconnect. Wire-harness failed. Ref FAA SDR 1997071700992. (item 95).

6/22/97. DC-9. On taxi out had elevator power fail. Return to gate. Replaced failed wire. Ref FAA SDR 1997072400064. (item 70).

7/3/97. DC-9. At cruise, something electrical is shorting in cockpit overhead panel. Wire shorted. Ref FAA SDR 19970722400519. (item 71).

7/5/97. DC-9, Northwest Airlines. At cruise smoke came from beneath glareshield. Shut off generators, declared emergency. Found burnt wires. NTSB Monthly CHI97IA195.

7/5/97. DC-9. At cruise smoke began filling cockpit from forward panel. Declared emergency. Found 4 feet of burned wires. Ref FAA SDR 1997071000444. (item 67).

7/15/97. DC-10. On climb had high oil temp, shut down # 2 engine. Unscheduled landing. Found shorted wire. Ref FAA SDR 1997081400787. (item 51).

7/28/97. 747. During cruise had sparks/smoke from seat 23-2. Replaced power cable and electronic unit. Ref FAA SDR 1997082100422. (item 58).

8/9/97. 747. On taxi had left wing overheat intermittent light on. Found shorted wire. Ref FAA SDR 1997081400977. (item 57).

8/14/97. DC-9. On approach main gear unsafe light fault. Found several failed wires at terminal block 53-66. Ref FAA SDR 1997100200689. (item 82).

8/25/97. DC-9. While in maintenance check, smoke and wire insulation damage was found near forward entry overhead. Ref FAA SDR 1997082800729. (item 76).

9/6/97. DC-9. On approach had gear warning fault, C/B found popped. Repaired wiring short. Ref FAA SDR 1997091100397. (item 78).

9/12/97. During taxi APU temp panel lights flickering and the smell of smoke in the cockpit. Found burned and chafed wires. Ref FAA SDR 1997091800828. (item 186).

9/21/97. 747. During climb had wing overheat light. Unscheduled landing. Found chafed wire at clamp. Ref FAA SDR 1997092500774. (item 61).

9/22/97. DC-10. During climb # 2 manifold fail light came on. Unscheduled landing. Replaced wires at manifold loop. Ref FAA SDR 19971000200322. (item 54).

9/25/97. DC-9. During climb had gear fault light. Replaced gear wiring harness and sensor. Ref

FAA SDR 19971000200331. (item 81).

9/29/97. 737. During cruise had APU fire warning. Pulled fire handle, light continued. Found wiring out of position. Ref FAA SDR 1997100200721. (item 189).

10/97. ASRS Report (de-identified). During preflight noticed light C/B popped. Sparks and wire arcing and worn insulation found. ASRS Rpt.# 382990.

10/15/97 767. Inspection found generator feeder cable chafed and burned near slat. Ref FAA SDR 1998012200841. (item 125).

152. 11/8/97. 767. During cruise left tank fuel quantity, and totalizer goes blank. Fault code included wiring. Ref FAA SDR 1997120400881. (item 117).

12/8/97. 767. During cruise left generator light flickering. Repairs to T-1 cable to IDG. Ref FAA SDR 1998011500726. (item 124).

12/30/97. 737. During climb unable to control pressurization. Returned to gate. Found C/B tripping, replaced PRSOV wiring. Ref FAA SDR 1998012200253. (item 203).

1/9/98 United Airlines flight 965, 767-322ER, arcing Kapton wires burned Cross-linked Tefzel wiring. Toxic gases emitted, wire-bundles burned. Ref. U.K. AAIB Rpt 5/2000 (EW/C98/1/3), para 1.12.3.8 and 1.18.2. (www.open.gov.uk/aaib/n653ua/n653ua.htm)

1/9/98. 767. During cruise had short circuit in P30 Panel near forward Chiller. Unshed landing. Severe wire-bundle damage. Ref FAA SDR 1998040800005. (item 129).

1/12/98. 737. Inspection found generator feeder cable and loom burnt due to arcing at the plug and socket. Ref FAA SDR 1998111300314. (item 276).

1/13/98. DC-9. On the gate the crew smelled smoke in the cockpit. Found broken wiring causing arcing at audio panel. Ref FAA SDR 199812200236. (item 84).

1/17/98. DC-10. During cruise # 1 start valve light illuminated. Unshed landing. Found chafed wiring near valve. Ref FAA SDR 1998012200529. (item 63).

1/18/98. DC-9. On taxi out had acrid electrical odor in cockpit. Light C/B popped. Return to gate. Suspect ballast or wiring. Ref FAA SDR 1998042900488. (item 99).

1/24/98. 737. During cruise a loud popping sound and a spark came out of cockpit overhead. C/B trips. Found shorted wire. Ref FAA SDR 1998031200994. (item 215).

1/25/98. 737. During cruise had engine fire faults. Reoccurring problem. Unshed landing. Engine core wiring harness faulted. Ref FAA SDR 1998022600675. (item 213).

6/27/98. 767. NTSB issues recommendations to the FAA on the Kapton wires on 767s due to the risk of in-flight fires or loss of control. The Kapton wires caused electricity to jump to control cables controlling the flight control surfaces. Ref A-98-1/2. (CNN 1/27).

1/29/98. DC-9. While at the gate smoke began coming in from battery compartment. Found broken wire. Ref FAA SDR 1998042900699 (item 100)..

3/1/98. Boeing declares arcing?sparking Kapton should be replaced with cross-linked Tefzel wire. Boeing Flight Summary Report 747-SRP-23-0057.

2/3/98. 767. During cruise flaps indicator jumps, also fault lights illuminated. Rewired at sensors and to wing root. Ref FAA SDR 1998043000009. (item 140).

2/6/98. 737. On climb gear would not raise. Unshed landing. Repaired wiring at gear logic shelf E11. Ref FAA SDR 1998031200971. (item 214).

2/8/98. DC-9. During decent had smoke in the cabin. Declared emergency. Repaired wire ends at S3-94. Ref FAA SDR 1998021900305. (item 87).

3/2/98. DC-9. During cruise a burning smell was detected in the rear cabin. Repaired broken wire at wire-bundle for lighting. Ref FAA SDR 1998043000771. (item 101).

3/6/98. 747. During cruise # 4 engine CSD over-temperature. Could Not Disconnect ! No cause found. Solder melted at disconnect. Ref FAA SDR 1998041701129. (item 83).

3/13/98. 747. On taxi out, # 4 engine start valve open light on. Returned to gate. Found wire insulation rotten at engine. Ref FAA SDR 1998032600261. (item 80).

3/15/98. DC-9. During climb the right engine start valve illuminated. Unshed landing. Repaired the engine wire-harness. Ref FAA SDR 1998043000860. (item 102).

- 4/10/98. 767. During cruise had electrical smell and haze at aft right galley. Only Chiller and fridge on. Repaired wiring. Ref FAA SDR 1998082800159. (item 140).
- 4/17/98. DC-10. Inspection found aft engine power feeder cables shorted at inlet duct panel # 364GR. Ref FAA SDR 199850100056. (item 74).
- 4/23/98. 737. During cruise # 2 slat transit light illuminated, a previous on 4/16. Unscheduled landing. Wire to be replaced. Ref FAA SDR 1998050100806. (item 230).
- 4/28/98. 737. Inspection found cockpit overhead wire-bundle chafed and burned. Ref FAA SDR 1998071700469. (item 242).
- 5/15/98. DC-9. During approach, nose gear downlock warning fault. Declared and emergency. Replaced gear wire-harness. Ref FAA SDR 1998052200834. (item 108).
- 5/16/98. MD11F. During taxi had # 3 engine vibration warning. Returned to gate. Found engine vibration wire-harness faulting. Ref FAA SDR 1998062000686. (item 45).
- 5/18/98. UPS 747-123 experiences uncommanded yaw inputs during cruise flight. Found to be a wire problem. Emergency landing. NTSB Monthly CHI98IA164.
- 5/20/98. DC-9. Inspection found APU power feeder cable shorted on a standoff. Ref FAA SDR 1998052900077. (item 109).
- 5/30/98. DC-10. After a smoke smell, found decoder harness and wires burnt under seat 22E. Ref FAA SDR 1998060500439.
182. 6/27/98. 737. After take off # 2 generator dropped off line. Could not reset. Unscheduled landing. Replaced generator wire-harness. Ref FAA SDR 1998120400507. (item 284).
183. 6/30/98. DC-9. Nose gear unsafe light illuminated. Replaced electrical harness. Ref FAA SDR 1998072400242. (item 112).
184. 7/15/98. DC-9. During cruise left generator tripped off. Losing hydraulics. Unscheduled landing. Wire arced through a hyd line. Ref FAA SDR 1998082100014. (item 114).
- 7/22/98. 747. Rejected takeoff due to cargo fire indication. Found chafed wire behind F/Es panel. Ref FAA SDR 1998080700341. (item 104).
- 8/14/98. 747. On taxi in C/B tripped for lights. Inspection found burnt and overheated wires and arcing. Ref FAA SDR 1998100900902. (item 112).
- 9/2/98. Swissair 111, MD-11- Investigation still ongoing, but Kapton and Tefzel wiring found that had arced. Mixed wiring types. Probable contributing factors may include incorrect routing/installation of the wiring.
- 9/24/98. 737. # 1 fuel heat valve came on, oil temp exceeded, shutdown engine. Returned to MCI. Found burned wire at valve. Ref FAA SDR 19981113000986. (item 278).
- 10/98. ASRS Pilot Report (de-identified). While in cruise, cabin crew noted smell of electrical fire. Diverted to alternate. ASRS Rpt. # 419315.
- 10/98. ASRS Pilot Report (de-identified). DC-10 dumped 85,000 lbs of fuel, declared emergency and diverted after smelling smoke in the cabin. ASRS Rpt. # 418250.
- 10/3/98. 767. While in cruise pax spilled drink in electric motor seat and shorted it out. Found chafed shorted wires near floor. Ref FAA SDR 1998100900432. (item 154).
- 10/8/98. MD-11, Delta Airlines. Two hours West of England enroute to Georgia experienced an electrical odor. Diverted to Ireland. NTSN Monthly # DCA99RA002. Also see FAA SDR 1998101600553; says "burned wiring to compressor" found. Item 51
- 11/98. L-1011 Kapton wiring arcs in cockpit behind circuit breaker panel. Emergency landing. Aircraft receiving conflicting electrical anomalies. Aircraft thought it was on the ground and in the air at the same time. Ref ASRS AB99:9/3-6
- 11/8/98. MD-11. Inspection found shorted wire in forward cargo which ignited Mylar insulation blanket. Ref FAA SDR 1998111301330. (item 52).
- 11/9/98. L-1011 Delta Airlines. Enroute between Honolulu and SFO, electrical fire in the cockpit. Numerous systems were lost. Emergency landing at San Francisco. Previous days had multiple electrical problems. NTSB Rpt. DCA99SA043 & ASRS Rpt. 419799.
- 11/9/98. DC-9. Inspection found smoke from lower EPC Panel. Found chafed and burned wires

near right AC relay. Ref FAA SDR 1998122400289. (item 124).

11/11/98. MD-11. At the gate a fire erupted in the forward cargo hold. Wiring damage led to a Mylar insulation blanket fire. Ref NTSB Recommendation Letter A-99-104 through 106, 12/15/99. See http://www.nts.gov/recs/letters/1999/A99_104_106.pdf

11/28/98. 747-400, Qantas Airlines. In flight fire in the E&E Bay. Arcing Kapton wiring ignites flammable insulation blankets. Emergency landing. Ref. NTSB Monthly Rpt. # DCA99WA014 and Ref. AAIB 5/200 (EW/C98/1/3), para 1.18.4 . Item 7.

11/28/98. 747. During climb saw equipment cooling caution. Found damaged and burned wiring & insulation blanket in fwd cargo area. Ref FAA SDR 1998011500351. item 117.

200. 11/30/98. MD-11F. During climb had faults; auto-pilot & throttles, Flt Dir, TAT, flaps, Press, Fan, etc. Returned, found 3 chafed wires. Ref FAA SDR 1998120400240. item 54.

12/25/98. DC-10. During climb had # 1 engine fire warning. Unscheduled landing. Found wire-harness at fault. Ref FAA SDR 1999010100129. (item 90).

12/22/98. L-1011, Delta Airlines. Before pushback, a passenger saw smoke and sparks from a sidewall vent. Two wire-bundles burned in the Mid Electrical Center. Wire to wire arcing, dust buildup and lav fluids were noted. A Delta Report said this was the fifth report of lav water, the eleventh report of wire to wire rubbing, the thirteenth report of excessive dirt buildup among Delta's 35 L-1011s. NTSB Monthly Rpt. # DCA99WA014.

12/29/98. DC-9. At gate, smoke in the cockpit and cabin. Crew saw an electrical Flash /Fire in comp left of door. Replaced wiring. Ref FAA SDR 1999010800058. (item 125).

1/29/99. 737. Inspection found chafed wires in center fuel tank level switch. Fuel found inside conduit. Ref FAA SDR 1999081200463. (item 357).

1/31/99. MD-11, American Airlines, smoke in the cabin. "Buzz" heard over PA system, C/B reset and then smoke seen in first class. Emergency declared, diverted to Seattle. Video system damaged, unknown connector failure. NTSB Accident Rpt. DCA99SA037

1/99. ASRS Pilot Report (de-identified). During cruise lost all pressurization, smoke in the cabin due to wiring caused electrical smoke. Emergency /divert. ASRS Rpt 424550.

2/13/99. MD-11. Inspection found electrical smell at row 13 and found electrical harness shorted out. Ref FAA SDR 1999021900341. (item 59).

2/16/99. DC-9. Inspection found left generator feeder cable shorting out in tail cone area. Bulkhead had a hole burned in it. Ref FAA SDR 1999022600217. (item 132).

2/99. ASRS Pilot Report (de-identified). DC-9 got failures of radio fan, GPWS, FDR, # 1 VHF, # 1 VOR, # 3 fuel boost pump, captain's ADI and CDI. Emergency decent to DTW. At gate, 11 more C/Bs popped.

2/99. ASRS Pilot Report (de-identified). DC-9-30 multiple unrelated electrical failures, most of left system lost but with no auto-transferring. Emergency landing. ASRS 428107.

2/23/99. MD-11. During overnight inspection aircraft would not accept power. Found wire burned and shorted in forward cargo bay. Ref FAA SDR 1999041700401. (item 63).

2/25/99. 737. On landing sparks and smoke in overhead panel behind fuel panel. Several C/Bs popped. Chafed wires behind panel. Ref FAA SDR 1999031200195. (item 327).

2/99. ASRS Pilot Report (de-identified). MD-11 U.S. While parked, a fire in a wire-bundle occurred. 14 wires found brittle and replaced. ASRS Rpt. 431017.

3/5/99. DC-10. Inspection found APU generator feeder cable shorting out at pressure bulkhead. Wire melted. Ref FAA SDR 1999031200607. (item 99).

3/99. ASRS Pilot Report (de-identified). 727 on TO had electrical smoke from the pilot's overhead panel. Pilot saw burned and charred wiring. ASRS Rpt. 429985.

3/29/99. MD-11, World Airways. During maintenance checks a Kapton wiring harness was found with chafed and arcing damage. Adjacent Mylar blankets also completely burned away. No cause listed. NTSB/Garvey letter, 12/15/99, NTSB Rpt. DCA99SA051.

3/31/99. DC-9. During climb had a loud pop and flash from the EPC C/B Panel, acrid smell. Found chafed power port feeder. Ref FAA SDR 1999043000409. (item 135).

4/9/99. 747. Inspection found # 2 main aft boost pump wiring insulation faulty. Ref FAA SDR 1999070900114. (item 134).

5/3/99. DC-9. During cruise the PSU oxygen masks dropped on the left side. Found wire shorted into forward lav pump under lav. Ref FAA SDR 1999051400001. (item 136).

5/10/99. 747. During inspection found C/B # 152 popped and smoked. Found wire chafing in overhead P5 Panel, wheel well fire Ref FAA SDR 1999061800610. (item 130).

5/16/99. DC-9. Aft left & fwd left fuel boost pump C/Bs popped, later the right side. Declared emergency. Damaged wire-bundle. Ref FAA SDR 1999062500762. (item 142).

5/18/99. 747. Inspection found trailing flap position wire in forward cargo ceiling shorted to ground. Ref FAA SDR 1999070900113. (item 133).

5/21/99. 737. During climb had smoke in the flight deck. Found wire chafed against bracket above P6-1 Panel. Ref FAA SDR 1999060400487. (item 337).

6/20/99. 737. During cruise faults with # 2 fuel gage. Replaced the # 1 and the # 2 wing tank harness assemblies. Ref FAA SDR 1999072300651. (item).

7/7/99. DC-10. Inspection found smoke/sparks in main gear bay. Wiring for # 2 Aux Hydraulic pump burned through but C/Bs not tripped. Ref FAA SDR 1999091000467.

7/8/99. 737. Inspection found 20 damaged wires in the vertical stabilizer and apparently damaged by hydraulic fluid near rudder PCU. Ref FAA SDR 1999081200849. (item 358)

7/27/99. 737. Inspection found system B hydraulic pump line chafing power wire-bundle causing short circuit. Ref FAA SDR 1999112500057. (item 391).

7/27/99. MD-11F. Inspection found forward cargo external power cable arcing below floor and bilge area insulation blanket burnt. Ref FAA SDR 1999073000464. (item 77).

7/31/99. 737. During cruise stabilizer trim actuator C/B pops. Found wires shorted to ground at bulkhead. Ref FAA SDR 1999081200236. (item 356).

8/3/99. MD-11. Inspection found seat 5G electrically inop. Found burned wire. Ref FAA SDR 1999081400461. (item 78).

8/10/99. 737. On takeoff left generator tripped. Smoke in cabin. Unscheduled landing. # 1 TR C/B tripped and generator feeder burnt. Ref FAA SDR 1999082000330. (item 361).

8/24/99. 737. During climb aircraft yawed. Unscheduled landing. Autopilot stabilizer trim wiring found damaged at aft bulkhead. Ref FAA SDR 1999102200599. (item 381).

8/27/99. 737. At climb interphone had ringing chimes, call lights flashing, smoke and flame at 3R Com panel. Wires replaced. Ref FAA SDR 1999102900318. (item 385).

9/2/99. 737. On takeoff # 2 bleed tripped off. Pressurization went to 9,500. Return to block. Wire Open to air bleed regulator. Ref FAA SDR 1999101300025. (item 374).

9/7/99. MD-88, Delta Airlines. During climb noted smoke in the cabin. Emergency and diverted. Mylar insulation burned 5 x 5 foot under floor. No cause. NTSB NYC99IA231. Also reference in NTSB/Garvey letter, 12/15/99 at ntsb.gov/recs/letters/1999/A99_104_106.pdf

9/21/99. MD-11. Inspection found sparks and smoke from under seat 11C. Wire-harness shorted to foot rest. Ref FAA SDR 1999100100110. (item 83).

9/25/99. 737. During climb had uncommanded right and left Yaw. Found a broken wire at forward end of E1 equipment rack. Ref FAA SDR 2000022900039. (item 417).

9/28/99. DC-9. Inspection found SELCAL system wire with burned insulation between station 110 to 160. Ref FAA SDR 1999100100341. (item 153).

10/9/99. 737. En route # 1 and 2 TRs tripped. Reset, tripped again. Electrical smell noted. Unshed landing. Replaced gen feeder harness. Ref FAA SDR 1999110500446. item 389

10/18/99. 737. During climb had smoke in aft galley. Unshed landing. Found shorted power wire behind galley. Ref FAA SDR 1999102900119. (item 384).

10/20/99. 737. Aborted takeoff after warning horn sound. Found chafing wire to # 4 SKEW sensor in wheel well. Ref FAA SDR 1999102900116. (item 383).

10/24/99. MD-11. Inspection found chafed and arcing wire at seat 3B, C/B did not pop. Replaced wiring harness. Ref FAA SDR 1999102900893. (item 85).

11/1/99. British 737-500 arcing kapton wiring in E/E bay, wire-bundle found completely charred. Ref . AAIB Rpt. 5/2000 (EW/C98/1/3) Para. 1.18.4.

11/2/99. 737. During climb both fuel flow indicators fluctuated. Unscheduled landing. Found chafed wire near # 1 engine. Ref FAA SDR 1999111100007. (item 390).

11/8/99. DC-10. During climb lost # 2 generator. Reset C/B. Smoke in the aft galley, gen off again. Found feeder wires shorted. Ref FAA SDR 1999111900011. (item 114).

11/9/99. DC-10. Inspection found fuel quantity fault. Wires in aux tank have insulation separation and damage. Ref FAA SDR 19991218000846. (item 119).

11/11/99. 737. During climb multiple C/Bs popped . Unscheduled landing. Found failure of the wire-bundle insulation at BS 410. Aircraft 772 wiring replaced. No system problems found for overload. Ref FAA SDR 1999122300026. (item 399). SEE NEXT.

11/11/99. 737. Alaska Airlines returned after popped C/Bs and low fuel lights. Follow up found additional C/Bs popped and heavily sooted and melted insulation in wiring bundles near cargo hold, station 410. NTSB Accident Rpt. SEA00IA019.

11/19/99. DC-9. During climb generator failed with AC cross lockout. Noted electrical odor. Unshed Landing. Feeder cable shorted. Ref FAA SDR 1999112500233. (item 156).

11/21/99. MD-11. Maintenance found arcing behind seat 13A caused by pinched cable. Ref FAA SDR 1999120400158. (item 88).

12/21/99. DC-10. Number 1 AC Bus C/Bs popping. Found burned wires in ceiling of forward compartment. Ref FAA SDR 1999011500634. (item 92).

1/10/00. 747. Inspection found APU generator feeder cable burned below cabin floor at BS 1450. Ref FAA SDR 2000042800255. (item 165).

1/18/00. DC-10. Inspection found electric hydraulic pump had 2 each shorted wires causing a fire. Ref FAA SDR 2000012900102. (item 122).

1/20/00. 737. During climb had fuel imbalance. Unscheduled landing. Replaced # 1 fuel quantity wire-harness. Ref FAA SDR 2000012000226. (item 407).

1/24/00. 737. During cruise generator tripped off twice. Third time could not reset C/B. Unscheduled landing. Replaced T1 wire. Ref FAA SDR 2000040800132. (item 425).

1/25/00. MD-11. During cruise coffee maker wire burned through but C/Bs did not pop. Ref FAA SDR 2000021200806. (item 91).

1/28/00. 737. While in climb aft lav smoke detector was sounding. Smell in cabin. Unscheduled landing. Found aged lav wire. Ref FAA SDR 2000050300165. (item 429).

1/31/00. 737. During climb fuel quantity indications decreased and erratic. Unscheduled landing. Repaired wires in right wing. Ref FAA SDR 2000022600044. (item 414).

2/2/00. 747. Inspection found generator feeder cable burnt at sta's 970, 980, and 985. Ref FAA SDR 2000022600048. (item 158).

2/8/00. DC-9. During pushback left pack fan C/Bs tripped. Found heat-exchanger wires chafing and shorted. Ref FAA SDR 2000021900295. (item 168).

2/8/00. 737. During decent # 1 generator Bus off light and systems loss. Declared emergency. Found chafed gen harness. Ref FAA SDR 2000042800409. (item 427).

4/16/00. 737. At climb pressurization fail light illuminated. C/B popped, no control. Wires damaged at controller and aft bulkhead. Ref FAA SDR 2000061000353. item 442.

4/17/00. 737. After liftoff wheel well C/B popped. Had previous repairs to wiring, and now found 20 wires burned at P18-3 panel. Ref FAA SDR 2000060300211. (item 440).

4/18/00. 737. During cruise left wing/body overheat light illuminated. Unscheduled landing. Found chafed shorted wire at APU. Ref FAA SDR 2000061000225. (item 441).

5/1/00. DC-9 On descent had smoke in the cockpit. Found a burnt wire going to map light. Ref FAA SDR 2000062400177. (item 177).

5/20/00.737, Electrical loom (bundle) arcing due to swarf in P6-4 C/B Panel. Overheated power receptacle, cause unknown. Ref . AAIB Rpt. 5/2000 (EW/C98/1/3) Para. 1.18.4.

6/10/00. 747. Inspection found wiring harness arcing at BS 520 in the forward cargo hold. Ref

FAA SDR 2000082200021. (item 172).

6/17/00. 737. Inspection found APU wiring melted behind starter connector and burned insulation in the E/E bay. Ref FAA SDR 200072500192. (item 466).

8/8/00. DC-9, Air Tran Airways. Flight returned to Greensboro with very dense smoke in the cockpit. Sparks and smoke seen the area of the forward FA jump seat. Emergency declared. Extensive wire damage in electrical panel behind captain's seat and blistering of the aircraft skin. Aircraft substantially damaged. NTSB Monthly # DCA00MA079.

10/1/2000, MD-80, Continental Airlines. Kapton arcing burns a fist sized hole in the cockpit. Cockpit filled with smoke. Emergency landing. NTSB Monthly ATL01IA001 and FAA Accident Rpt at http://www.faa.gov/avr/aai/D_1002_N.TXT.

John D. King, IASA Data Specialist at jking1@mediaone.net.

INSTRUCTIONS TO LOCATE SOURCE URSs AND AGENCIES IN THIS IASA STUDY

NTSB Monthly <http://www.nts.gov/aviation/months.htm> Search By Year And Date.

NTSB Recommendations http://nasdac.faa.gov/asp/asy_searchus.asp Search By Report Number.

NTSB Accident/Incident http://nasdac.faa.gov/asp/asy_ntsb.asp Search By Report Number.

FAA Incident Data System http://nasdac.faa.gov/asp/asy_fids.asp Search By Report Number.

Cross System Search to each of the above http://nasdac.faa.gov/asp/asy_crosssys.asp.

ASRS REPORTS At http://nasdac.faa.gov/asp/asy_asrs.asp Search By Report Number.

NASDAC's Aviation Safety Data Accessibility Study Index http://nasdac.faa.gov/safety_info_study

'Heinrich Pyramid' http://nasdac.faa.gov/gain/Presentation/GAIN_Brief.pdf ref page 7 of 42.

MILITARY WIRING ISSUES SEPARATED FROM ABOVE LIST 18 ITEMS

May 1995, Royal Air Force Nimrod, wires arc and fire starts. Aircraft lost.

July 20 1998, Army Command issued to all AH-64 helicopter users to inspect the Kapton wiring which could contribute to uncommanded inputs.

September 4, 1999 NASA's entire Shuttle fleet grounded for 6 months for Kapton wiring problems.

October 17, 1988, NASA's Magellan Spacecraft experiences \$87,000 electrical fire due to Kapton wiring.

1983 NASA's Columbia Shuttle orbiting earth experiences Kapton wire fire.

1985, NASA's Space Lab used in the shuttle, experiences Kapton wire fire.

March 30, 1987, F-18 Kapton wire fire nearly dooms \$32 million aircraft.

November 1982, Air Force's F-16 experiences Kapton arc-tracking. Pilot/Aircraft lost.

August 24, 1990 US Coast Guard's E-2C crashed due to Kapton wire fire.

November 2000- US Navy loses 153rd F-14 out of 600 produced. Requested \$360 million in FY 83 to rewire F-14s due to wire to wire shorts caused by premature aging and cracking of Poly-X wire type used in first 323 aircraft produced.

May 31, 1982-December1, 1981- In just six months the Air Force experiences 800 autopilot

May 31, 1982-December 1, 1981- In just six months the Air Force experiences 800 autopilot anomalies due to wiring.

March 1986-US Navy AV-8B in-flight electrical fire caused by Kapton wiring. Fourth occurrence in six month period.

1988 US Military, Canadian and British military ban Kapton.

March 1987, Vermont National Guard F-16, arcing Kapton caused nine wire-bundles to be destroyed.

May 1985, EF 111 Air force jet has a catastrophic explosion of Kapton wires. 92 wires damaged, 29 circuit breakers popped.

September 11, 1986 Marine AV-8B Harrier emergency landing, inoperative critical instruments, several burned bundles of Kapton wires.

January 27, 1982 US Navy F-4, Electrical in-flight fire in circuit breaker 10 inches from co-pilot's feet. Thick smoke in the cockpit/all electrical power lost. Emergency landing.

October 1987, US Navy A-6 aircraft lost at sea. Kapton wire only suspected cause.

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15 ITEMS NOT POSTED DUE TO LACK OF OTHER SOURCES

11/28/00. DC-9, Air Tran. Flight 956 returned to Hartsfield, Ct after smoke was detected in forward galley and cockpit C/Bs tripped. Evacuation was made on the runway. Passengers were given 1,000 dollars each for lost luggage and claims of luggage damaged in the fire. News wire stories.

http://www.accessaltanta.com/partners/ajc/newsatlanta/airtran_1129.html

<http://www.ohio.com/dist/nf/021801.htm>

http://dailynews.yahoo.com/h/ap/20001201/bs/plane_fire_1.html

<http://www.herald.com/thispage.htm?content/archive/news/yahoo/digdocs/055368.htm>

11/16/00. 747, United Airlines. Smoke filled one of the kitchens. Emergency landing at Seattle-Tacoma. News wire story. www.airsafetyonline.com/news/200011/16/5.shtml

11/3/00. 757 American Airlines. 757 reported smoke in the cockpit. Emergency declared and landed in Miami Int'l airport. News

http://dailynews.yahoo.com/hwplg/20001103/lo/240762_1.html

10/19/00. 747 United Airlines diverted to Auckland because of electrical problems. News wire story

<http://www.pprune.org/ubb/NonCGI/Forum1/HTML/010545.html>.

10/18/00. 757, National Airlines. Flight 7002 returned and landed due to a fire in the galley. FAA Incident Reg 546NA. News wire story. http://www.faa.gov/avr/aai/D_1018_N.TXT

10/6/2000. MD-80, American Airlines. Denver to LA Flight 2821 diverted to Bryce Canyon Airport after reports of smoke in the cabin and oxygen masks were deployed. News wire story.

<http://more.abcnews.go.com/sections/travel/DailyNews/Emerglanding001006.html>.

9/27/2000. MD-80 (or 90), American Airlines. Returned to Omaha Airport after departing DFW and an occurrence of smoke in the cockpit. No further detail.

8/24/99. MD-90. Uni Air. On landing at Hualian, Taiwan flight 873 (Reg B-17912) heard a loud noise from the front of the cabin and thick black smoke poured from one of the overhead compartments on the right side. It took firefighters a half hour to control the blaze. 28 people were injured. News wire story. <http://aviation-safety.net/database/1999/990824-0.htm>

8/13/00. 757, Continental Airlines. Diverted into Ketchikan with electrical failures. Possible 'Red Eye' out of ANC. No details.

7/23/00. 757, British Airways. Possible cabin fire and divert to Heathrow (LHR). No details.

7/23/00. 757, British Airways. Possible cabin fire and divert to Heathrow (LHR) . No details.
 7/17/2000. MD-80, American Airlines. DFW to Orlando, flight 1258 diverted to Dallas Fort Worth after reports of smoke in the cockpit. Emergency over wing evacuation. AP Wire.

<http://more.news.abcnews.go.com/sections/travel/DailyNews/smokecockpit000717.html>

6/15/00. MD-80, Continental Airlines. According to FAA records “the 1981 MD80 has been repaired for small cracks, dents, fluid loss, burned wires and electrical problems”. News wire story. <http://www.bergen.com/news/lurch200006155.htm>

2/29/00. 747-300. Reg # PU-BUH. From EHAM (Amsterdam) to PANC (Anchorage) made a emergency decent into Prestwick (PIC) after report of a main cargo-deck fire. No detail.

7/16/99. American Airlines. Flight 2191 made a emergency landing at the naval station in the Florida Keys after the pilot said he smelled smoke aboard the Miami to Cancun flight with 162 aboard. AP Wire. No details.

3/12/99. 767, United Airlines. Flight 971 Washington to Milan. Smoke detected, emergency and diverted to Newfoundland. CNN News wire. END _____

10 MISCELLANOUS ITEMS NOT POSTED FOR LACK OF ADDITIONAL REFERENCES

1981. TWA asks the Boeing Company not to use Kapton on their 767s. Boeing refuses.

July 12, 1987. Boeing 767-232 has all three autopilots fail.

August 10, 1990. Delta 767-332 made an emergency landing due to loss of engine due to chafed Kapton wiring.

February 1, 1995. Monarch 757, Kapton wire-bundles arc, knocking out cockpit displays.

May 28 1998. Continental 737, arcing wires burn hole in conduit, explosive condition, All 737s grounded with more than 51% showing exposed conductors.

September 22, 1999. SAAB SF-340-B Emergency landing/Smoke in the Cockpit due to chafed wire from autopilot system.

November 1, 1999. Canada’s Transport Canada acknowledges Kapton wire problems. Ref British AAIB Report 52/87.

31 Jan 00. DC-9. Nightingale/Skytrain.Reg # MWT107 While parked at the gate pilot was advised of a fire in the aft Lav with minor damage. Passengers deplaned. FAA Incident *.

March 2, 2000. British Airways 747 Flt 179 experiences abrupt climb injuring 11, FAA determines, “The aircraft experienced an uncommanded autopilot climb”. (USA Today)

March 3, 2000. Kapton banned from use by Austrailian Airline.

109 ADDITIONAL ITEMS POTENTIALLY “WIRE” RELATED BUT NOT SPECIFICALLY MENTIONED

12/7/84, 727, Republic Airlines. TO aborted, smoke and arcing from P611 Panel. Heat and smoke damage near left ground blower. FAA Incident Rpt # 19841207070859C.

4/8/85. DC-9-82. American Airlines. During cruise, C/Bs opened for transformer rectifiers at AC Panel. FAA Incident Rpt # 19850408014749C.

12/31/85. DC-3, Private charter. Dense smoke in cockpit from fire originating in aft cabin. Ignition and fuel source undetermined. NTSB Recommendations Rpt # A-85-91.

8/10/86. DC-10, American Trans Air. Fire in the forward cargo hold on the ground. No probable cause determined. NTSB Monthly Rpt. # DCA86IA037.

11/26/86. 727, Continental Airlines. While on ground a cargo fire started. APU generator C/B found smoldering. FAA Incident Rpt. # 19861125069939C.

5/26/87. 737, Southwest Airlines. While in climb, smoke was seen in the aft galley. Pulled

5/26/87. 737, Southwest Airlines. While in climb, smoke was seen in the aft galley. Pulled breakers, unable to duplicate. FAA Incident Rpt. # 19870526022979C.

11/28/87. 747, South African Airways. Crashed into the sea with all 160 lost. Last ATC communication suggested an in flight fire. NTSB Recommendation Rpt. # A-88-61.

2/3/88. DC-9, American Airlines. Smoke in the cabin, soft/hot floor above cargo area. No causes to the fire were noted. NTSB Recommendation Rpt.# A-88-121 & A-88-128.

4/88. ASRS Pilot report (de-identified). While at cruise, smelled a strong electrical smell, Lost # 1 Main AC and generator. ASRS # 86076.

4/88. 737, Continental Airlines. On final, a fire in the ceiling continued to burn through insulation blankets and duct insulation. Fire department called. Ref. DOT/FAA/CT-91/2.

10/88. ASRS Pilot Report (de-identified). During pre flight a fire erupted in the center pedestal. Even with Halon and power off fire continued to burn. ASRS. # 96957.

1/89. ASRS Pilot Report (de-identified). Aborted TO after a loud noise from Main C/B Panel. 5 C/Bs popped. Tried again, 10 C/Bs popped. Declared Emer. ASRS # 101677.

2/2/89. DC-9, Swissair. Fire developed in the C/B Panel. Flt diverted and Emergency evacuated. Ref. Letter and FAA testimony Senate hearing (103-397) on 11/8/93.

4/89. ASRS Pilot Report (de-identified). Declared a emergency out of IAH and diverted back for Smoke in the cockpit. ASRSRpt # 109853.

4/89. ASRS Pilot Report. After push back at Fayetteville Regional crew advised of smoke in the cabin. Emergency evacuation followed. ASRS Rpt # 109801.

6/89. DC-10, Canadian Airlines. Apparent arcing of light fixture ignited surrounding insulation blankets and the fire spread to ceilings and walls. Ref. DOT/FAA/CT-91/2.

8/17/89. 737, Delta Airlines. While on final, electrical failures, Number 2 and Number 3 Power Transformer Rectifier C/Bs had tripped. FAA Incident Rpt.# 19890817052289C.

10/14/89. 727, Delta Airlines. While parked, a muffed explosion and flames came from the vent near seat 3D. No cause was found. NTSB Monthly Rpt. # DCA90MA002.

10/89. ASRS Pilot report (de-identified). Smoke in the cockpit and cabin, declared emergency. Same problem several days later. ASRS Rpt # 127334.

12/1/89. DC-9, American Airlines. At cruise, found electrical smell like an overheated electrical system. Found burnt terminals and C/B. FAA Incident # 19891201062979C.

1/10/90. 747, Northwest Airlines. Found heat damage around aft cargo mid-ship drain mast. Components tested but no probable cause. NTSB Monthly Rpt. # CHI90IA064.

1/90. ASRS Pilot Report (de-identified). Electrical shutdown and cockpit filled with smoke. Declared emergency and diverted. ASRS Rpt. # 134261.

4/6/90. DC-9, Midway Airlines. From cruise, electrical problems. Diverted, replaced C Phase C/B. FAA Incident Rpt. # 19900406022459C.

8/90. ASRS Pilot Report (de-identified). Near VUZ, AL heard loud "Pop" noise followed by the smell of electrical smoke. Informed ATC, continued to IAH. ASRS Rpt # 155020.

09/90. ASRS Pilot Report (de-identified). Immediately after TO from Cleveland Hopkins, smoke in the cabin, emergency declared and returned. ASRS Rpt. # 157942.

9/90. ASRS Pilot Report (de-identified). Left Denver gate, smoke filled cabin. Could not see past 1st class. PA did not work. Emergency evacuation. ASRS Rpt. # 157908.

2/1/91. DC-9, U.S. Air. On arrival experienced a fire in the aft cargo hold. Bags scorched but no sources within the hold were found. NTSB Monthly Rpt. # MIA91SA230.

11/93. ASRS Pilot Report (de-identified). Near St Louis Int'l at 23,000 attendant reported smoke and fumes in cabin. Declared emergency and landed. ASRS Rpt. # 256013.

11/93. ASRS Pilot Report (de-identified). On taxi out smelled smoke, returned. Next flight, cockpit began to fill with smoke. Emergency divert. ASRS Rpt. # 258014.

4/26/94. 737, Aloha Airlines. Gear position, PA, Interphone and thrust reversers not working. Cabin smoke, evacuation. Source not found. NTSB Monthly Rpt. # LAX94IA206.

6/94. ASRS Pilot Report (de-identified). Rancid cockpit odor on takeoff from Atlanta. Emergency

declared. Autopilot inop. Electrical smell noted. ASRS Rpt. # 276367.

7/94. ASRS Pilot Report (de-identified). 737 on takeoff, gear retract, TO warning, transponder, pressurization malfunctioned. Cabin odor. Diverted. ASRS Rpt. # 278033.

7/94. ASRS Pilot Report (de-identified). At cruise following systems failed or faulted; equipment cooling fan light, Dual DC fail IRS, Battery Buss, anti skid, both N1 and EGT indicators, Com 2, Capt ADI and HIS, autopilot, reverser lights, red gear lights, elevator feel light and PA system. Emergency, saw thick cabin smoke. ASRS # 278111.

9/94. ASRS Pilot Report (de-identified). 727 observed erratic fuel flows and then strong electrical odor in the cockpit. Emergency declared. Fire dept called. ASRS Rpt. # 282510

9/94. ASRS Pilot Report (de-identified). MD-11, both pilots saw smoke coming from overhead cargo test panel. Diverted to EWR.. ASRS Rpt. # 284198.

2/10/95. DC-9, TWA. Smoke in the cockpit, diverted to Omaha. Cause not determined. Aircraft returned to service. FAA Incident Rpt. # 19950210006589C.

2/16/95. DC9, Sunjet Int'l Airlines. At 27,000 experienced a pressurization problem with associated smoke in the cockpit Emergency decent. FAA Incident Rpt 19950216005639C

3/95. ASRS Pilot report (de-identified). Inflight, smoke, fumes and "pop". Possible window short. Ran checklist. Declared emergency, diverted to BNA. ASRS Rpt 299362.

3/13/95. 737, Delta Airlines. Crackling sound, brief fire, smoke and fumes upper right hand corner of R-1 window. C/Bs did not pop. FAA Incident Rpt. # 19950313006819C.

5/5/95. ASRS Pilot Report. At 27,500 United DC-10 lost all generators. Deployed emergency generator. Emergency landing. No cause found. ASRS Rpt. # 303757.

5/28/96 Martinair 767-31AER experienced repeated electrical anomalies, uncommanded auto-pilot disconnects, changes in airplane zero fuel weight, and blanking of transponder codes. Emergency landing. Kapton wiring suspected. Other anomalies observed on two other 767s. Ref. NTSB Monthly NYC96IA116.

5/15/96. 747. On descent noticed spark under seat 3B. One fire bottle used to extinguish the spark. Ref FAA SDR 1996071100004. (item 18).

9/95. ASRS Pilot Report (de-identified). During cruise heavy smoke in the cabin. Emergency divert to Nassau. Claimed FAA Investigation. None found. ASRS # 315585.

1/96. ASRS Pilot Report (de-identified). 727 at 29,000 smoke came from under FO forward panel. Divert to TLH. Same problem in another 727 weeks later. ASRS # 326301

1/96. ASRS Pilot Report (de-identified). 737 during cruise total loss of all electrical power. After APU start emergency divert to CMH. ASRS Rpt. # 326327.

1/96. ASRS Pilot Report (de-identified). 757 smoke in the cabin. Declared a emergency, landed in San Francisco. ASRS Rpt. # 325089.

2/9/96. DC-9. On take off EPR system C/B popped. Return to gate. Could not duplicate the problem. Ref FAA SDR 1996030800454. (item 14).

2/96. ASRS Pilot Report (de-identified). During climb smoke billowed out of aft galley. Emergency evacuation on ramp. Cause not determined. ASRS Rpt. # 328795.

2/25/96. DC-9. VALUJET. While sitting at the gate C/B trips for PA, Interphone, No Smoking and Fasten seat Belts. Smoke in cabin. Accomplished VJ E.O. DC-9-3396005. Ref FAA SDR 1996060600422. (item 29).

5/15/96. DC-10. During cruise multiplex system power shorted out and sparked with smoke in the cabin at seats 33DE. Ref FAA SDR 1996052300007. (item 22).

8/96. ASRS Pilot Report (de-identified). 767 East of Nova Scotia smoke in the cockpit. Declared emergency and landed overweight at Sidney. ASRS Rpt. # 344573.

8/14/96. DC-10 While at cruise a oxygen generator activated over Row 26-28. Right side of aircraft had strong electrical smell. Ref FAA SDR 1996082200603. (item 28).

8/30/96. 747. During landing sparks and smoke emitted from under seat 31-7. Cable shorted, activated fire extinguisher. Ref FAA SDR 1996102400370. (item 29).

9/4/96. 737, U.S. Air. Gear failed to retract, Air/ground C/B popped. Unable to duplicate the

problem. Aircraft returned to service. FAA Incident Rpt. # 19960904033669C.

9/5/96. DC-10, Federal Express. At 33,000ft smoke in the cabin cargo compartment. Emergency landing at Stewart. No cause found. NTSB Monthly Rpt. # DCA96MA079.

9/96. ASRS Pilot Report (de-identified). After TO cabin reported very strong electrical smoke. Emergency return to IAD. C/Bs did not trip, no cause found. ASRS Rpt.# 348982

9/8/00. DC-9. During cruise left engine overheat warning. Declared an emergency and landed. Found tripped C/B, no cause found. Ref FAA SDR 19960911200448. (item 40).

10/20/96. 737, U.S. Air. Smoke in the cockpit, diverted to Ithaca N.Y. FAA Ferry permit was issued. "Case considered closed". Ref. FAA Incident Rpt. # 19961020037309C.

10/29/96. DC-9. At cruise, B phase C/B popped and then all forward fuel boost pumps, then A phase & others. Unscheduled landing. Ref FAA SDR 1996110100943. (item 46).

11/96. ASRS Pilot Report (de-identified). While at cruise noted strange odor and fumes in cockpit. Equipment overheat light on. Declared emergency/landed. ASRS 353804.

11/16/96. DC-9. During cruise left AC Buss C/B popped. Numerous C/b trips and system loss followed. Unscheduled landing. Ref FAA SDR 1996121900650. (item 52).

12/96. ASRS Pilot Report (de-identified). While taxiing to gate, smoke came out from behind FO control panel. ASRS Rpt. # 355635.

12/19/96. DC-9. At takeoff, center aft fuel boost pump C/B popped. All quantity gages went blank. Reset failed. Unscheduled landing. Ref FAA SDR 1996122600330. (item 53).

1/97. ASRS Pilot Report (de-identified). 737 during cruise had multiple systems fail. Standby power and APU would not work. Emergency, divert. ASRS Rpt. # 358949.

1/97. ASRS Pilot Report (de-identified). DC-9 on ground had smoke coming from the E&E bay. Fire dept called. Batteries found smoking. ASRS Rpt.# 357142.

3/9/97. DC-10. Overhead cabin panels rows 25 to 26 began arcing and smelled smoke. Unable to find cause. Ref FAA SDR 1997031300703. (item 44).

5/97. ASRS Pilot Report (de-identified). 737 had cabin smoke and heat reported. Emergency declared, diverted to alternate. ASRS Rpt. # 369599.

5/97. ASRS Pilot Report (de-identified). MD-80 at 11,000 feet reported electrical smell in the cabin. Declared an emergency. ASRS Rpt. # 370087.

6/17/97. DC-10, Sun Country Airlines. Smoke in the aircraft. Emergency landing to Denver. Two crew members hospitalized. NTSB Monthly Rpt. # FTW97IA227.

10/97. ASRS Pilot Report (de-identified). While taxiing cabin reported increasing electrical smoke. C/Bs did not pop. Return to gate. Next flight same again. ASRS 382946

10/29/97. DC-9. During cruise lavatory door, when locked, shocked a passenger. Replaced wire. Ref FAA SDR 1998042800555. (item 98).

11/97. ASRS Pilot Report (de-identified). 767-200ER had electrical smoke. Declared emergency, returned to the Azores. Second such diversion/month. ASRS Rpt. # 385050.

12/19/97. 737, Singapore Airlines. Reg # 9V-TRF. Flight MI-185 exploded in mid-air. Ref. <http://www.airdiasters.co.uk/191297.htm>. No cause or Report available here.

12/19/97. MD-80, Alaska Airlines. Taxiing to gate when cabin filled with smoke. Over wing evacuation to the taxiway. Ref. www.nts.gov/Publictn/2000/SS0001.pdf "case 4".

12/25/97. 737, United Airlines. In flight smelled electrical burning and noted landing gear C/B popped. Left main gear collapsed on landing. Ref. www.nts.gov/Publictn/2000/SS0001.pdf "case 5".

1/7/98. MD-11F. Inspection found wiring burned up beneath center cargo floor. Also noted bellframe burned through. Ref FAA SDR 1998011500120. (item 40).

1/11/98. Boeing 767 Emergency landing, Kapton wires arced popping circuit- breakers and smoke in the cabin. Ref Boeing Service Message M-7200-98-00140, 6/21/98.

1/19/98. 737, Continental Airlines. Enroute, C/Bs for # 1 Main, aft boost in # 2 Main and both pumps in the center and aux fuel tank popped. Only 2 pumps remained operational Replaced C/B #65. Ref. FAA Incident Rpt. # 19980119002309C. Case closed.

1/19/98. 737, Continental Airlines. Enroute, C/Bs for # 1 Main, aft boost in # 2 Main and both pumps in the center and aux fuel tank popped. Only 2 pumps remained operational Replaced C/B #65. Ref. FAA Incident Rpt. # 19980119002309C. Case closed.

1/9/98. Boeing 767 emergency landing due to intermittent leading edge disagreement, electrical smoke and fumes in the cabin. Ref Boeing Service Message M-7200-98-00140, 6/21/98. (Ref NTSB Monthly DCA98RA016).

3/27/98. DC-9. Air Canada. On taxiout, experienced a electrical fire in the cockpit overhead panel. Source was ignition switch. NTSB Monthly Rpt. # CHI98A110.

3/30/98. 727 Royal Airlines. Ft Lauderdale. Before TO crew smelled smoke in the cockpit. Flames and smoke coming from the overhead panel. Evacuated using chutes. Ref. NTSB_ www.nts.gov/Publictn/2000/SS0001.pdf , "case 13".

4/4/98. 767, Britannia. Diverted by damaged sidewall heater and arcing electrical fire burned a hole in a panel and insulation blankets. AAIB of Iceland to investigate. NTSB Monthly Rpt. DCA98WA046.

4/98. ASRS Pilot Report (de-identified). At cruise, smelled strong electrical smell. Haze in the cabin. Made straight in landing. ASRS Rpt. # 40075.

4/98. ASRS Pilot Report (de-identified). C/B popped for left AC Buss. Reset but popped again. Could not reset again. Emergency and diverted to Detroit. ASRS Rpt.# 400849.

4/98. ASRS Pilot Report (de-identified). Enroute, Transfer Buss C/B popped. Would not reset. Lost instruments and pressurization control. Emergency / divert. ASRS # 400987.

5/15/98. Type ?, United Airlines. Smoke, sparks and flames from C/B Panel C787. Fire put out, flight landed and 411 passengers offloaded. FAA Incident # 19980515014099C.

5/98. ASRS Pilot Report (de-identified). Lost all cabin PA systems. Smelled electrical odor in cockpit. Called for emergency equipment and landed. ASRS Rpt. # 401039.

6/22/98. 757-2Y0, Air 2000 Ltd. Experienced a loud bang and sparks from cockpit overhead panel. Flight diverted. UK AAIB investigating. NTSB Monthly DCA98WA057.

7/98. ASRS Pilot Report (de-identified). 737 noted cracking sound behind C/B panel. Equipment and pressurization failures. Diverted to alternate. ASRS Rpt. # 408309.

8/98. ASRS Pilot Report (de-identified). 767-300 abeam of Nova Scotia had smoke in the cockpit. Declared emergency, landed overweight at Sydney, N.S. ASRS Rpt. # 344573.

3/22/99. DC-10. During cruise a loud spark arced, then several more times later in flight near the lower inst panel. No cause found. Ref FAA SDR 1999041700441. (item 104).

4/7/99. 737, Turkish Airlines. Became engulfed in fire shortly after TO and crashed. Ref. <http://www.airdiasters.co.uk/070499.htm> . No cause or Report found here.

6/22/99. 737, United Airlines. Enroute, smoke in the cabin. Diverted to Scottsbluff. Unable to find cause, returned to service. FAA Incident 19990622018839C. Case Closed.

7/31/99. 737. For Two Flights, during climb had engine overheat fault. Unscheduled landings. Replaced engine soft core harness. Ref FAA SDR 1999090300679. (item 366).

9/8/99. 747. During cruise lost 50 % electrical power. Unscheduled landing. Wire/water contaminated in galley. Ref FAA SDR 2000022300014. (item 157).

2/26/00. DC-9/80, U.S. Air. Reg # USA1248. At Indianapolis, Pilot declared smoke in the cockpit. Two Flight attendants hospitalized for smoke inhalation. FAA Incident*.

5/7/00. 717 Air Tran Airways. Smoke in the cockpit coming from near the fuel pump switches. Declared an emergency. No cause, switches sent for tests. NTSB MIA00SA147.

7/12/00. 727, Federal Express. Reg # FDX3106. Smoke in the cockpit. Declared an emergency and evacuated on the runway at Fort Worth. FAA Incident. Source; www.faa.gov/avr/aai/D_0717_N.TXT

7/12/00. 777-200, British Airways. Enroute Toronto to London reported smoke in the cockpit and declared a emergency, divert to Montreal. Cadors Rpt 2000A0378.

7/21/00. DC-9, Northwest Airlines. Reg # 671Mc. On TO had smoke in the cockpit. Returned and evac pax to the runway. FAA Incident faa.gov/avr/aai/D_0724_N.TXT

8/10/00. 767, Delta Airlines. DAL 139 enroute Manchester to N.Y. reported electrical smoke in the cockpit East of Labrador. Diverted to Goose Bay. Cadors Rpt # 2000A0454.

10/18/00. 757, National Airlines. Flight 7002 returned and landed due to a fire in the galley. FAA Incident Reg 546NA. http://www.faa.gov/avr/aai/D_1018_N.TXT

11/11/00. 737, U.S. Air. Reg # USA1862. Reported smoke in the cabin. Unknown. FAA Incident. http://www.faa.gov/avr/aai/D_1113_N.TXT

11/15/00. 747, United Airlines. Reg # UAL809. Flight 809 reported smoke in the galley. Emergency and diverted to Seattle. FAA Incident www.faa.gov/avr/aai/D_1116_N.TXT

11/20/00. A-300, American Airlines. At 16,000 feet neither pressurization controllers would work. F/A chimes sounded erratically and the forward lav smoke detector sounded. After landing, ram air switch would not depressurize aircraft. Captain then reported a fire and called to emergency evacuate. F/A opened a door and was expelled from the aircraft and killed. NTSB Monthly MIA01FA029.

11/29/00. MD-80, American Airlines. Flight 1683. Flight attendant report of smoke in the cabin. Emergency landing at Reagan Nat'l and evacuation to the ground using slides and chutes. FAA Incident http://www.faa.gov/avr/aai/D_1130_N.TXT

Limitations

The aircraft events listed here are limited to the larger types of commercial transports, all reports to the commuter-type craft (i.e. Beech, Saab, ATRs) were discarded even though they also operated under the same Part 121 commercial carrier rules and, as the same carriers seen in this report, shared the same materials in wiring insulation types and insulation blanket (batts) used in their 'big cousins'.

Under reporting is a big problem and as NASDAC had noticed, there are significant limitations to the self-reporting processes and such may apply in the Aviation Safety Reporting System Database (ASRS) Reports used here. The same limitations may well apply to the newly announced system by the White House in late January 2000 dubbed the Aviation Safety Action Program (ASAP). This encompasses virtually all of the claims cited for the creation of the earlier ASRS system in 1983, including immunity from prosecution and claims for heightened safety awareness and information sharing.

The NASDAC studies (see source on page 12) also noted that such aviation mishaps subject to self reporting often go unreported because of; (1) by themselves, they may appear insignificant, (2) the event wasn't intentional, (3) no one is hurt because of back up systems or (4) no collation is seen to other events. The latter may easily be attributed to lack of information sharing, which ironically, is why these programs were set up in the first place. Never-the-less, NASDAC agrees the actual calls placed to ASRS are but a fraction of the industry incidents and occurrences.

Moreover, NASDAC made note of the Heinrich Pyramid (see source on page 15) whereas for every given major accident, there will be 3-5 less significant accidents, and among 7-10 incidents, there may be at least several hundred unreported occurrences. Thus, with the ASRS voluntary reports here, unreported incidents may have ranged considerably higher.

The FAA's Service Difficulty Reporting Lastly, a separate IASA Study demonstrated that within the Office Of System Safety Databases, and all linked to a common search engine, that the FAA Incident Data System Reports reflected but less than 5 % of the combined reports from the other databases listed there.

Edited by jking1@mediaone.net.

John D. King
IASA Data Specialist

The International Aviation Safety Association is a non profit safety organization incorporated in New York.
See our website at www.IASA.com.au .

Chairman: Mrs. Lyn Susan Romano

**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

**Appendix H Miscellaneous Accidents
(Unofficial)**

A 50-Year Snapshot of Crash Causes

Accident Causes

1950s

1960s

1970s

1980s

1990s

Total

Pilot Error

38%

36%

26%

26%

26%

30%

Pilot Error (weather related)

10%

16%

14%

16%

4%

14%

Pilot Error (mechanical related)

5%

4%

4%

3%

2%

4%

All Pilot Error

53%

56%

44%

45%

42%

48%

Other Human Error

3%

8%

9%

6%

9%
7%
Weather
17%
11%
15%
17%
15%
15%
Mechanical Failure
21%
17%
20%
16%
23%
19%
Sabotage
6%
5%
10%
15%
10%
9%
Other Cause
0%
3%
2%
1%
1%
2%

Source: BACK Associates and PlaneCrashInfo.com database

Accident	Killed
1 March 27, 1977 Two Boeing 747s operated by Pan American and KLM collide at the airport on Tenerife in Spain's Canary Islands	582
2 Aug. 12, 1985 Japan Air Lines Boeing 747 crashes into a mountain on a domestic flight	520
3 March 3, 1974 Turkish DC-10 crashes northeast of	

- Paris
346
- 4
June 23,
1985
Air-India Boeing 747 crashes off the
coast of Ireland. Investigators conclude
a bomb caused the crash
329
- 5
Aug. 19,
1980
Fiery emergency landing of a Saudi
Arabian L-1011 jet at the airport in the
Saudi capital of Riyadh
301
- 6
July 3,
1988
Iran Air A300 Airbus shot down by USS
Vincennes over the Persian Gulf
290
- 7
May 25,
1979
American Airlines DC-10 crashes on
takeoff in Chicago
273
- 8
Dec. 21,
1988
Pan Am Boeing 747 crashes in
Lockerbie, Scotland. A terrorist bomb
was blamed
270*
- 9
Sept. 1,
1983
Korean Air Lines 747 shot down by a
Soviet fighter after flying through Soviet
airspace near Sakhalin Island
269
- 10
April 26,
1994
A China Airlines A300-600R Airbus
exploded and burned during an aborted
landing in Nagoya, Japan
262

* 259 people were killed on the plane, 11 on the ground

Source: The Associated Press

Civil Aviation Safety Documentation Archive - CASDA

This listing contains all jet airliners, involved in bombings:
The list contains the following information:

#	number	date	Type	registration	operator	no. of casualties (no. of occupants) + cas. on the ground	location of accident
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Bombings aboard jet aircraft

#1 22.05.62 Boeing 707-124

N70775 Continental Air Lines (USA)
45(45) Unionville; 6mls NNW (USA)

While on its way from Chicago to Kansas City at FL390, a bomb exploded in the right rear lavatory. Consequently, the tail section separated, and the aircraft crashed out of control.

CAUSE: Detonation of dynamite in a towel container.

#2 12.10.67 de Havilland DH-106 Comet 4

G-ARCO British European Airways - BEA (UK)
66(66) Rodhos, 100nm off; 35°55'N 30°01'E (Greece)

After a turnover of 1h 20mins at Athens, flight CY284 departed at 02.41h. Flying at FL290, a bomb exploded under seat 4A or 5A in the rear of the tourist cabin. At FL150 the Comet broke up and crashed into the sea.

#3 11.12.67 Boeing 727

N..... American Airlines (USA)
0(78) Alamosa, over (USA)

One hour and 42mins after take-off from Chicago, a small explosion occurred in the rear baggage compartment. The Boeing was able to make a safe landing.

CAUSE: Home made bomb exploded.

#4 19.11.68 Boeing 707-324C

N17325 Continental Air Lines (USA)
0(70) Gunnison; over (USA)

While descending through FL240 towards Denver, an explosion took place in the lavatory, followed by a fire. A safe emergency landing was made.

The passenger, seen leaving the lavatory just before the explosion, was arrested by the FBI.

#5 11.03.69 Boeing 707

Ethiopian Airlines

0(0) Frankfurt-Rhein Main APT (Germany)

On the ground, two explosions took place in the tourist class passenger compartment.

#6 21.02.70 Sud Aviation SE-210 Caravelle VIR

OE-LCU Austrian Airlines (Austria)

0(38) Frankfurt; nr. (Germany)

At FL100, 20mins after take-off from Frankfurt, an explosion in the forward freight hold blew a hole of 3'x2' through the bottom of the fuselage. The Caravelle safely returned to Frankfurt.

#7 21.02.70 Convair CV-990-30A-6

HB-ICD Swissair (Switzerland)

47(47) Zürich; nr. (Switzerland)

An explosion in the aft of the plane, about 9mins. after take-off. The Convair crashed, while returning to the airport.

#8 24.08.71 Boeing 707

Alia Jordanian Airlines

0(0) Madrid-Barajas (Spain)

An explosive device in the aft lavatory complex blew a hole in the top fuselage (3ft long). Luckily the aircraft was parked at the time.

#9 21.11.71 Sud Aviation SE-210 Caravelle III

B- 1852 China Airlines (Taiwan)

25(25) Penghu Island; nr. (Taiwan)

The aircraft crashed into the sea on a flight from Taipei to Hong Kong. CAUSE: Probably caused by a bomb explosion.

#10 26.01.72 McDonnell Douglas DC- 9-32

YU-AHT Jugoslovenski Aerotransport - JAT (Yugoslavia)

27(28) Krussne Hory Mt (Czech.)

An inflight explosion in the forward cargo hold of a homemade bomb at FL100 caused the DC-9 to break up and crash. The surviving crew member fell 15000ft in the tailsection!

CAUSE: Bomb placed on the aircraft by the Croatian extremists organisation 'Ustasji'.

#11 08.03.72 Boeing 707-331

N761TW Trans World Airlines - TWA (USA)

0(0) Las Vegas-McCarran IAP (USA)

A bomb exploded in the right rear part of the cockpit while the aircraft was

parked.

#12 25.05.72 Boeing 727-116
 CC-CAG LAN Chile (Chile)
 0(50) Cuba, nr ()

One hour and 18mins after take-off from Panama City a homemade pipe bomb exploded in the ice water fountain service compartment. A rapid decompression followed. A successful emergency landing at Montego Bay was made at 13.10h.

#13 15.06.72 Convair CV-880-22M-21
 VR-HFZ Cathay Pacific Airways (Hong Kong)
 81(81) nr Pleiku (Vietnam)

The Convair (Flight CX 700Z) took off from Bangkok at 04.55h GMT bound for Hong Kong. While flying at FL290 a bomb exploded, hidden in a suitcase under a passenger seat on the right side over the wing.

The bomb was put on the aircraft by a police officer whose daughter and fiancée were aboard.

#14 16.08.72 Boeing 707
 4X-A.. El Al (Israel)
 0(148) over Roma (Italy)

A bomb in a portable record player (stored in the aft baggage compartment) exploded shortly after take-off. The 200grams of explosive just caused a hole in the baggage compartment. The Boeing landed safely back at Roma.

#15 22.03.74 Sud Aviation SE-210 Caravelle III
 F-BRSY Air Inter (France)
 0() Bastia (France)

On the ground an explosion occurred in the forward landing gear compartment, causing substantial damage.

#16 26.08.74 Boeing 707
 Trans World Airlines - TWA
 0() Roma (Italy)

After landing in Roma, a fire was discovered in the aft baggage compartment. The fire was caused by an explosive device which malfunctioned.

#17 08.09.74 Boeing 707-331B
 N8734 Trans World Airlines - TWA (USA)
 88(88) Cephalonia; 58mls W off (Greece)

En route to Athens, a bomb exploded aboard TWA Flight 841. The Boeing entered a steep climb, went into a steep nose down spin and crashed into the Ionian Sea. The bomb was placed in the aft cargo compartment.

#18 03.06.75 BAC One-Eleven 524FF

RP-C1184 Philippine Air Lines (Philippines)

1(64) nr Manila (Philippines)

During descent into Manila (at FL200) a bomb exploded in the right lavatory in the rear of the plane. The explosion caused a hole in the fuselage of 1.3m x 4m. A successful emergency landing was made.

#19 05.07.75 Boeing 707

Pakistan International Airlines - PIA

0() Rawalpindi (Pakistan)

On the ground after a flight from Karachi a bomb, placed under a passenger seat, exploded. The explosion ripped a 3ft x 4ft hole in the fuselage.

#20 01.01.76 Boeing 720-023B

OD-AFT Middle East Airlines - MEA (Lebanon)

81(81) Al Qaysumah; 20nm NW (Saudi Arabia)

En route at FL370 from Beirut to Dubai, a bomb exploded in the forward baggage compartment. The aircraft crashed into the desert.

#21 07.09.76 Boeing 707-328

F-BHSH Air France (France)

0(0) Ajaccio (France)

Seven masked men set dynamite explosives aboard the aircraft and caused the explosion.

#22 06.10.76 McDonnell Douglas DC- 8-43

CU-T1201 Cubana (Cuba)

73(73) Bridgeport; 5mls W off (Barbados)

At 17.15h Flight 455 took off from Bridgetown Runway 09, heading for Kingston. Nine minutes later, the crew tried to turn back to Barbados due to an explosion. The DC-8 lost height rapidly and crashed in a nose down, right wing low attitude into the sea, 5 miles offshore.

CAUSE: An explosive device detonated in the rear of the cabin, which resulted in an uncontrollable fire, possibly causing crew incapacitation.

#23 17.08.78 BAC One-Eleven 524FF

RP-C1184 Philippine Air Lines (Philippines)

1(84) Sinara Island; over (Philippines)

En explosion in the rear left lavatory blew a hole in the fuselage. The aircraft was flying at FL240 at the time, on its way from Cebu to Manila.

#24 26.04.79 Boeing 737-2A8

VT-ECR Indian Airlines (India)

0(67) Madras (India)

On its way from Trivandrum to Madras, the aircraft was cleared to descent

from FL270. Shortly afterwards an explosion took place in the forward lavatory, causing a complete instrument and electrical failure. The Boeing had to make a flapless landing at Madras. The aircraft touched down 2500ft past the Runway 25 threshold and overran. The right side of the plane caught fire.

CAUSE: As a result of the explosion, the flaps, reverse thrust and anti-skid systems couldn't be used during the emergency landing.

#25 15.11.79 Boeing 727

N..... American Airlines (USA)

0(78) Chicago; nr. (USA)

Thirty minutes after leaving Chicago, a bomb device hidden in a wooden box in a mail bag detonated. This resulted in pressure fluctuations and smoke in the cabin. A safe landing was made at Washington-Dulles.

FBI thinks the bomb was placed aboard by the 'Unabomber', who was responsible for a number of attacks on universities and airlines since 1978.

#26 09.09.80 Boeing 727

N..... United Air Lines (USA)

0(44) Sacramento (USA)

While passengers were deplaning, a small cardboard box blew up in the cargo hold and injured two cargo handlers.

#27 21.12.80 Sud Aviation SE-210 Caravelle VIR

HK-1810 TAC Colombia (Colombia)

70(70) Guajira (Colombia)

At 14.18hrs the Caravelle took off from Rio Hacha for a flight to Medellin. Five minutes after take-off an explosion occurred and there appeared to be a fire in the right-hand aft portion of the aircraft. The Caravelle went out of control and crashed.

The aircraft was on its first scheduled flight after 17 months of maintenance work.

It's not known for sure whether the explosion was caused by a bomb or not.

#28 31.08.81 Boeing 720-023B

OD-AFR Middle East Airlines - MEA (Lebanon)

0() Beirut IAP (Lebanon)

Shortly after arriving from a flight from Libya, an explosion of approx. 5kgs of dynamite destroyed the aircraft.

#29 13.10.81 Boeing 737-2K2C

PH-TVC Air Malta (Malta)

0(0) Cairo IAP (Egypt)

While offloading luggage a porter and 3 security guards were injured when two parcels exploded about 15mins apart. A third bomb which didn't detonate, was located later.

#30 12.12.81 Boeing 727-025

YN-BXW Aeronica (Nicaragua)
0() Mexico City (Mexico)

When the passengers were ready to embark the plane, a bomb exploded between the rearmost cabin seat on the left aisle and the cabin wall. The blast tore a 3ft hole in the fuselage. The captain, 2 stewardesses and an airport mechanic were injured.

The aircraft was preparing for a flight to San Salvador.

#31 11.08.82 Boeing 747-121

N754PA Pan American World Airways (USA)
1() Hawaii; 140mls (USA)

On a flight from Tokyo one passenger was killed when a bomb, located under the seat cushion, exploded. The explosion also resulted in a hole in the floor and damage to the ceiling and overhead racks. A safe landing was made at Honolulu.

#32 19.08.83 Boeing 727-294

YK-AGA Syrian Arab Airlines (Syria)
0(12) Roma (Italy)

During boarding a glass bottle containing flammable liquid, located under a seat in the passenger area near the right overwing emergency exit, caused a fire. The interior of the plane completely burned out.

#33 23.09.83 Boeing 737-2P6

A40-BK Gulf Air (Oman)
112(112) Mino Jebel Ali (UAE)

After a brief distress message, the aircraft crashed in the desert. Evidence indicated that a bomb had exploded in the baggage compartment. The aircraft was on a flight from Karachi to Abu Dhabi.

#34 18.01.84 Boeing 747

Air France
0(261) Karachi, 70mls (Pakistan)

An in-flight explosion after leaving Karachi blew a hole in the right rear cargo hold and caused a loss of cabin pressure. An emergency descent to 5000ft was made and the aircraft returned to Karachi.

#35 10.03.84 McDonnell Douglas DC- 8-63PF

F-BOLL Union de Transportes Aériens - UTA (France)
0(23) N'Djamena (Tchad)

Twenty minutes after arriving from Brazzaville, a bomb exploded in the central baggage compartment.

#36 23.01.85 Boeing 727-2K3

CP-1276 Lloyd Aéreo Boliviano - LAB (Bolivia)

1(127) Santa Cruz; 30nm (Bolivia)

While descending through FL100 a passenger went into the forward lavatory carrying a dynamite in a briefcase. The dynamite exploded, killing the passenger. The aircraft made a safe landing at Santa Cruz.

#37 09.03.85 Lockheed L-1011 TriStar 500

Royal Jordanian Airlines

0() Dubai IAP (UAE)

On ground at Dubai, after a flight from Karachi, a bomb exploded in a baggage compartment.

#38 23.06.85 Boeing 747-237B

VT-EFO Air India (India)

329(329) Atlantic Ocean ()

The aircraft broke up in flight at FL310 and crashed into the Ocean.
CAUSE: A bomb, placed on board by a Sikh terrorist, caused a powerful explosion.

#39 30.10.85 Boeing 727

American Airlines

0() Dallas-Fort Worth (USA)

An explosion occurred in the forward baggage compartment while baggage was being unloaded.

The device was contained in a vinyl tote bag.

#40 02.04.86 Boeing 727-231

N54340 Trans World Airlines - TWA (USA)

4(121) Kérkira (Corfu); over (Greece)

While descending through FL100 a bomb exploded, causing a 1,40 x 1,60m hole in the fuselage. Four passengers fell off the aircraft. The aircraft landed safely at Athens.

#41 26.10.86 Airbus A.300B4-601

HS-TAE Thai Airways International (Thailand)

0(239) nr Shimizu (Japan)

An explosion at FL330 caused a rapid decompression and the loss of 2 hydraulic systems.

The Airbus made an emergency descent with a max of 2.6g and landed safely.

CAUSE: A passenger attempted to smuggle handgrenade into Japan but it exploded in the aft toilet.

#42 29.11.87 Boeing 707-3B5C

HL-7406 Korean Air (South Korea)
115(115) Andaman Sea; 14°33' N 97°23' E ()

At 00.01h UTC Koream flight 858 departed Abu Dhabi for a flight to Seoul via Bangkok. At 05.01h UTC the last message was received. It appeared that a bomb explosion aboard caused the crash.

Two passengers who had left the plane at Abu Dhabi, left a radio and liquor bottle containing hidden explosives in the overhead rack at row 7.

#43 21.12.88 Boeing 747-121A
N739PA Pan American World Airways (USA)
259(259) + 11 Lockerbie (UK)

The aircraft disintegrated at FL310 after a bomb exploded in the forward cargo hold. Large pieces of debris fell into a residential area of Lockerbie.

#44 19.09.89 McDonnell Douglas DC-10-30
N54629 Union de Transportes Aériens - UTA (France)
171(171) Ténéré desert; 16°54'N 11°59'E (Niger)

Flight UTA 772 (Brazzaville - N'Djamena - Paris CDG) departed N'Djamena at 12.13h. While climbing through FL350, 21mins after take-off, a pentryt bomb exploded near seat 13R. The DC-10 disintegrated and crashed in the desert.

The bomb was probably placed on board at Brazzaville.

The DC-10 had accumulated 60.267 flying hours and 14.777 cycles.

#45 27.11.89 Boeing 727-21
HK-1803 Avianca (Colombia)
107(107) nr Bogota (Colombia)

The aircraft exploded shortly after take-off

#46 18.03.91 Ilyushin 86
SSSR-..... Aeroflot (Russia)
0(360) Sverdlovsk (Russia)

A psychiatric patient threw a petrol bomb, which caused an on-board fire. An emergency landing was made at Sverdlovsk.

The aircraft was on its way from Moscow to Novokuznetsk.

#47 10.12.94 Boeing 747-283B
EI-BWF Philippine Air Lines (Philippines)
1(293) Minami Diato Isl.; nr. (Japan)

On a flight from Manila to Tokyo via Cebu, a bomb exploded in the passenger cabin beneath seat 26K. A successful emergency landing at Okinawa was made at 12.45h.

The muslim group Abu Sayyaf claimed responsibility.

Bombings aboard jet aircraft : statistics

Departure airport ranking:

Karachi (Pakistan) - 4 times
Athens (Greece) - 3 times
Roma (Italy) - 3 times
Chicago (USA) - 3 times
Brazzaville (Congo) - 2 times
Cebu (Philippines) - 2 times

Total casualties:

1626

(including 11 casualties on the ground at Lockerbie and 70 casualties of a Colombian Caravelle of which it's not sure whether a bomb caused the accident or not).

Total aircraft destroyed:

23

Total aircraft destroyed in-flight:

16

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1. Tenerife, Canary Islands, March 27 1977 - 583 killed
KLM Boeing 747-206B runs into Pan Am Boeing 747-121 on runway
2. Tokyo, Japan, August 12 1985 - 520 killed
JAL Boeing 747SR-46 crashes into mountain, 4 survivors
3. Charkhi Dadri, India, November 12 1996 - 349 victims
Saudi Arabian Airlines Boeing B747-168B collides in mid-air with Kazach Ilyushin Il-76TD
4. Ermenonville, France, March 3 1974 - 346 killed
DC-10 Series 10 of THY Turkish Airlines cargo door bursts open - crashes in a forest
5. Irish Sea, June 23 1985 - 329 killed
Air India Boeing 747-237B, terrorist bomb
6. Riyadh, Saudi Arabia, August 19 1980 - 301 victims
Saudia L-1011-200 Tristar bursts into flames after emergency landing

7. Kinshasa, Zaire, January 8 1996 - 297+ killed
Overloaded African Air Antonov-32 crashes into market place - 4 of 5 crewmembers survive
8. Persian Gulf, July 3 1988 - 290 dead
USS Vincennes downs Iran Air Airbus A300B2-202
9. Chicago, USA, May 25 1979 - 273 dead
American Airlines DC-10 Series 10 crashes due to damaged hydraulics
10. Lockerbie, Scotland, December 21 1988 - 270 killed
Libyan terrorists bomb attack on a Pan Am Boeing 747-121A
11. Sakhalin Island, USSR, September 1 1983 - 269 perished
Soviet Su-15 downs a Korean Air Lines Boeing 747-230B
12. Nagoya, Japan, April 26 1994 - 264 dead
China Airlines Airbus A300B4-622R, 9 survivors
13. Jiddah, Saudi Arabia, July 11 1991 - 261 fatalities
Nationair Canada DC-8 Super 61 leased to Nigeria Airways catches fire after take-off caused by blown tires
14. Ross Island, Antarctica, November 29 1979 - 257 dead
Air New Zealand DC-10 Series 30 flies into polar mountain
15. Gander, Canada, December 12 1985 - 256 fatalities
Arrow Air Inc. DC-8 Super 63PF crashes during take-off
16. Pancur Batu, Indonesia, September 26 1997 - 234 killed
Garuda Indonesia Airways A300B4-220, 222 pax, crashes in bad visibility conditions due to forest fires
17. New York, USA, July 17 1996 - 230 perished
TWA Boeing 747-131 crashes into ocean near Long Island due to exploding center fuel tank
18. Peggy's Cove, Canada, September 3 1998 - 229
Swissair MD-11 crashes in the Atlantic after fire-problems, no survivors among the 215 passengers

19. Guam, Pacific Ocean, August 6 1997 - 225 fatalities
Korean Airlines Boeing 747 fails to make a correct approach, 29 survive

20. Ban Nong Rong, Thailand, May 26 1991 - 223 killed
Lauda Air Boeing 767-3Z9ER goes down after thrust reverser problems

21. Maharashtra, India, January 1 1978 - 213 killed
Air India B-747-237B explodes in mid-air

22. Taipeh, Taiwan, February 16 1998 - 204 fatalities
China Airlines Airbus A300-622R crashes during retried landing, also killing 15 crew and 7 on the ground

23. Uch Kuduk, Uzbekistan, USSR, July 10 1985 - 200 fatalities
Aeroflot Tupolev 154B-2, goes into flat spin and crashes

24. Maskeliya, Sri Lanka, December 4 1974 - 191 dead
Martinair DC-8 Series 55F hits moutain

25. Puerto Plata, Dominican Republic, February 6 1996 - 189 perished
Alas Nacionales Boeing 757-225 crashes into Atlantic due to wrong air speed indication

26. Immouzer, Morocco, August 3 1975 -188 killed
Alia Royal Jordanian Airlines Boeing 707-321C hits moutain

27. Katunayake, Sri Lanka, November 15 1978 - 184 killed
Icelandair DC-8 Super 63CF ploughes into a coconut plantation, 78 survivors

28. Warsaw, Poland, May 9 1987 - 182 killed
LOT Il-62MK crashes when two engines catch fire at an altitude of 8200 meters

29. Mejorada del Campo, Spain, November 27 1983 - 181 fatalities
Avianca Boeing 747-283B Combi crashes during approach, 11 survivors

30. Ajaccio, Corsica, December 1 1981 - 180 fatalities
Inex Adria Aviopromet Yugoslav DC-9 Super 82 crashes into mountain on approach

31. Zanderij, Surinam, June 7 1989 - 177 killed
Crew of SLM DC-8 Super 62 ignores tower instructions, 10 survivors
32. Krasnaya Polyana, USSR, October 13 1972 - 176 dead
Ilyushin-62 crashes into a lake, ILS inoperative
33. Kano, Nigeria, January 22 1973 - 176 fatalities
Alia Royal Jordanian B-707-3D3C crashes during landing due to landing gear damage
34. Zagreb, Yugoslavia, September 10 1976 - 176 dead
Mid-air collision between Inex-Adria DC-9 Series 32 and BA Hsa Trident 3B, ATC language error
35. Dneprodzerzhinsk, USSR, August 11 1979 - 173 killed
Two Aeroflot Tu-134's collide at an altitude of 8000m
36. TÈnÈrÈ Desert, Niger, September 19 1989 - 170 dead
Terrorist bomb aboard a Union de Transportes AÈriens DC-10 Series 30
37. San Andres mountains, Mexico, March 31 1986 - 167 killed
Mexicana Boeing 727-264, tyre burst causes fuel leak
38. Kathmandu, Nepal, September 28 1992 - 167 fatalities
Pakistan International Airlines A300B4-203 crashes on approach
39. Alma-Ata, USSR, July 7 1980 - 163 fatalities
Aeroflot Tu-154B-2 crashes shortly after take-off
40. Lagos, Nigeria, September 27 1992 - 163 fatalities
41. Morioka, Japan, July 30 1971 - 162 dead
All Nippon Airways B-727-281 collides with JASDF F-86F Sabre
42. Havana, Cuba, September 3 1989 - 160 dead
Cubana de Aviacon Il-62M crashes killing all 126 aboard and 34 on ground
43. Xian, China, June 6 1994 - 160 fatalities
China Northwest Tupolev 154M

44. Cali, Columbia, December 20 1995 - 160 killed
Boeing 757-223 of American Airlines hits mountain, 4 survivors
45. Mauritius, Indian Ocean, November 28 1987 - 159 fatalities
South African Airways Boeing 747-244B self-igniting fire-works
46. Tripoli, Lybia, December 22 1992 - 157 fatalities
Jamahiriya Lybian Arab Airlines Boeing Advanced 727-2L5 collides with MiG-23
47. Sch[^]nefeld, GDR, August 14 1972 - 156 killed
Interflug Gesellschaft Il-62 catches fire in rear fuselage
48. At Ta'if, Saudi Arabia, November 26 1979 - 156 victims
Pakistan International Airlines, B-707-340C, fire starts in the aft-cabin, total destruction
49. Detroit, USA, August 16 1987 - 156 perished
Northwest Airlines MD-82, slats not extended on takeoff, crashes on highway
50. Maracaibo, Venezuela, March 16 1969 - 155 perished
VIASA DC-9 Series 32 hits electric power line, crashes in suburb
51. Tenerife, Canary Islands, December 3 1972 - 155 killed
Spantax Covair 990-30A-5 Coronado, loss of control on take-off
52. Isparta, Turkey, September 19 1976 - 155 fatalities
THY Boeing Advanced 727-2F2, wrong airport assumed, hits moutain
53. Kenner, USA, July 9 1982 - 153 killed
Pan Am B-727-235 carrying 145 flies into thunderstorm crashes into suburbs
54. Omsk, USSR, October 15 1984 - ±150 victims
Aeroflot Tu-154 collides with fuel truck on runway
55. Bilbao, Spain, February 19 1985 - 148 dead
Iberia Boeing Advanced 727-256 crashes into TV antenna atop Mt Oiz
56. Tenerife, Canary Islands, April 25 1980 - 146 fatalities
Dan-Air Services B-727-46 crashes into moutain on approach

57. San Diego, USA, September 25 1978 - 144 died
Mid-air collision between Pacific Southwest Airlines B-727-214 and Cessna 172M
58. Palo Alto, Azores, February 8 1989 - 144 dead
Independent Air Inc. Boeing 707-331B hits mountain, communication error with tower
59. Longyearbyen, Spitsbergen, Norway, August 29 1996 -143 killed
Vnukovo Airlines Tu-154M crashes on arrival
60. Liutang, China, November 24 1992 - 141 fatalities
China Southern B-737-3YO hits mountain due to vibration in starboard engine
61. Kahengula, Angola, December 19 1995 - 141 perished
Trans Service Airlift Chartered Lockheed 188C Electra
62. Lagos, Nigeria, November 7 1996 - 141 victims
Nigerian Aviation Development Company Boeing B727 crashes into lagoon
63. Cucuta, Colombia, March 17 1988 - 139 killed
AVIANCA B-727-21, flies into mountain due to pilot error
64. Pacatuba, Brazil, June 8 1982 - 137 victims
Viacao Aerea Sao Paulo Boeing Advanced 727-212, pilot is distracted by lighted city
65. Dallas, USA, August 2 1985 - 137 perished
Delta Airlines Lockheed L-1011-1 Tristar encounters microburst
66. New York, United States of America, December 16 1960 - 134 killed
United Airlines DC-8 Series 11 collides with TWA Lockheed 1049 Super Constellation
67. Tokyo Bay, Japan, February 4 1966 - 133 dead
All Nippon Airways B-727-81 crashes, cause unknown
68. Medellin, Columbia, May 19 1993 - 133 fatalities
Aeronautics Society of Medellin Boeing 727-46 carrying a crew of 7
69. Belarussia, USSR, June 28 1982 - 132 casualties
Aeroflot Yakovlev 42 carrying 124 passengers and a crew of 8

70. Canton, China, October 2 1990 - 132 dead
Hijacked Chinese Boeing Advanced 737-247 first hits an empty B-707-3J6B and then a B-757-21B
71. Teheran, Iran, February 8 1993 - 132 fatalities
Mid-air collision of an Iran Air Tu-154M and a Sukhoi fighter
72. Pittsburgh, USA, September 8 1994 - 132 fatalities
USAir Boeing 737-3B7
73. Funchal, Portugal, November 19 1979 - 131 victims
TAP Boeing Advanced 727-282, overruns runway, plunges of cliff, strikes a bridge, 33 survivors
74. Las Mesitas, Honduras, October 21 1989 - 131 fatalities
TAN Airlines Boeing 727-224 hits moutain on approach, 19 survivors
75. Orly, France, June 3 1962 - 130 killed
Air France B-707-328 crashes on take-off
76. Sverdlovsk, USSR, November 11 1967 - 130 killed
Aeroflot Il-18 crashes due to radar failure
77. Lubango, Angola, November 8 1983 - 130 dead
TAAG-Angola Airlines Boeing Advanced 737-2M2 shot down by guerrillas
78. Gujarat India, October 19 1988 - 130 killed
Indian Airlines B-737-2A8 undershot runway hits trees and high-tension pylon
79. Tokyo, Japan, June 18 1953 - 129 dead
Engine failure on take-off USAF C-124 Globemaster II
80. South Vietnam, December 24 1966 - 129 fatalities
Military chartered Canadair CL-44
81. The Grand Canyon, USA, June 30 1956 - 128 perish
Mid-air collision between UAL DC-7 and TWA Lockheed 1049 Super Constellation

82. Markazi, Iran, January 21 1980 - 128 killed
Iran Air B-727-86 crashes due to ILS malfunction
83. Voronezh, USSR, March 5 1976 - 127 fatalities
Aeroflot Ilyushin 18D, pressurization failure during approach
84. Comoro Islands, November 23 1996 - 127 casualties
Hijacked Ethiopian Airlines B767-260ER runs out of fuel, crashes near shore, 48 survive
85. Nicosia, Cyprus, April 20 1967 - 126 killed
Globe Air Bristol Britannia 313 crashes on landing
86. Damascus, Syria, August 20 1975 - 126 killed
Ceskoslovenske Aerolinie Ilyushin-62 hits sandy hill during approach, 2 survivors
87. Irkutsk, Russia, January 4 1994 - 125 perished
Aeroflot Tupolev 154M goes down due to bad maintenance
88. Mount Fuji, Japan, March 5 1966 - 124 perish
BOAC B-707-436, fatigue cracks in a bolt hole
89. Windhoek, South-West Africa, April 20 1968 - 123 fatalities
South African Airways B-707-344C crashes on take-off, 5 survivors
90. Saulx-les-Chartreux, France, July 11 1973 - 123 killed
Varig Boeing 707-345C, total fire during descent, 11 survivors
91. Arequipa, Peru, February 29 1996 - 123 dead
Faucett B-737-222 crashes burning into mountain
92. Cairo, Egypt, May 20 1965 - 121 killed
Pakistan International Airlines B-720-040B, nose-down condition, 6 survivors
93. Cuenca, Ecuador, July 11 1983 - 119 fatalities
TAME Boeing Advanced 727-2V2, tail section strikes a ridge, crashes into hilly terrain
94. Sainte Thérèse de Blainville, Canada, November 29 1963 - 118 killed
Trans Canadian DC-8 Series 54F, in-flight explosion

95. Heathrow, England, June 18 1972 - 118 killed
British European Airways HS-121 Trident 1C, crew failed to diagnose premature 'droop'
retraction
96. Leningrad, USSR, April 27 1974 - 118 fatalities
Aeroflot Ilyushin 18V has a take-off accident
97. Mont Blanc, Switzerland, January 24 1966 - 117 perished
Air-India B-707-437, bad atmospheric conditions
98. Carini, Sicily, May 5 1972 - 115 fatalities
Alitalia DC-8 Series 43 crashes into mountain
99. New York, USA, June 24 1975 - 115 dead
Eastern Airlines B-727-225 crashes due to windshear, 9 survivors
100. Andaman Sea, November 29 1987 - 115 dead
Korean Air B-707-3B5C, North Korean bomb attack

© EJECT! Aviation Homepage 1998 07/17/1996 c 18:45
LOCATION: East Moriches, NY
CARRIER: Trans World Airlines FLIGHT: 800
AIRCRAFT: B-747-131 REGISTRY: N93119
ABOARD: 230 FATAL: 230 GROUND:
DETAILS: Exploded in-flight at FL 130.

10/04/1992
LOCATION: Amsterdam, Netherlands
CARRIER: EI AI FLIGHT:
AIRCRAFT: B-747-258F REGISTRY: 4X-AXG
ABOARD: 5 FATAL: 5 GROUND: 47
DETAILS: Lost an engine while in flight caused by corroded pins.

12/29/1991
LOCATION: Wanli, Taiwan
CARRIER: Air China FLIGHT:
AIRCRAFT: B747-2R7F REGISTRY: B-198
ABOARD: 5 FATAL: 5 GROUND:
DETAILS: Crashed on takeoff after losing engine due to corroded pins.

11/27/1989 c 07:20
LOCATION: Near Bogota, Columbia

CARRIER: AVIANCA FLIGHT: 203
AIRCRAFT: B-727-21 REGISTRY: HK-1803
ABOARD: 107 FATAL: 107 GROUND: 3
DETAILS: Detonation of an explosive device in the passenger compartment under a seat.

09/19/1989 c 14:00
LOCATION: Near Bilma Niger
CARRIER: Union de Transportes Aeriens (France) FLIGHT: 772
AIRCRAFT: DC-10-30 REGISTRY: N54629
ABOARD: 170 FATAL: 170 GROUND:
DETAILS: Detonation of an explosive device in the forward baggage compartment.

02/24/1989
LOCATION: Honolulu, HA
CARRIER: United Airlines FLIGHT: 811
AIRCRAFT: B-747-122 REGISTRY: N4713U
ABOARD: 356 FATAL: 9 GROUND:
DETAILS: Improperly latched cargo door. Loss of door in-flight, explosive decompression.
Nine sucked out of plane.

12/21/1988 c 19:00
LOCATION: Lockerbie, Scotland
CARRIER: Pan American World Airways FLIGHT: 103
AIRCRAFT: B747-121 REGISTRY: N739PA
ABOARD: 259 FATAL: 259 GROUND: 11
DETAILS: Detonation of an explosive device in the forward cargo area.

04/28/1988
LOCATION: Maui, HI
CARRIER: Aloha Airlines FLIGHT: 243
AIRCRAFT: B-737-297 REGISTRY: N73711
ABOARD: 95 FATAL: 1 GROUND:
DETAILS: Separation of top of fuselage and explosive decompression. Metal fatigue. One
passenger sucked out.

11/29/1987 c 11:30
LOCATION: Over Andaman Sea
CARRIER: Korean Air FLIGHT: 858
AIRCRAFT: B707-3B5C REGISTRY: HL-7406
ABOARD: 115 FATAL: 115 GROUND:
DETAILS: Detonation of an explosive device in the passenger compartment.

11/28/1987 c 04:00
LOCATION: Over Indian Ocean
CARRIER: South African Airways FLIGHT: 295
AIRCRAFT: B-747-244B REGISTRY: ZS-SAS
ABOARD: 159 FATAL: 159 GROUND:
DETAILS: Fire in the main cargo area. Hazardous materials in the cargo hold.

04/02/1986
LOCATION: Near Athens, Greece

CARRIER: Trans World Airlines FLIGHT:
AIRCRAFT: B-727 REGISTRY:
ABOARD: FATAL: 4 GROUND:
DETAILS: Detonation of a explosive device in the passenger compartment causing four passengers to be sucked out.

06/23/1985 c 07:15
LOCATION: Atlantic Ocean, Near Ireland
CARRIER: Air India FLIGHT: 182
AIRCRAFT: B-747-237B REGISTRY: VT-EFO
ABOARD: 329 FATAL: 329 GROUND:
DETAILS: Detonation of an explosive device in the forward cargo hold. Aircraft broke up in flight.

09/23/1983 c 15:30
LOCATION: Near Mina Jebel Ali, UAE
CARRIER: Gulf Air FLIGHT: 717
AIRCRAFT: B-737-2P6 REGISTRY: A40-BK
ABOARD: 112 FATAL: 112 GROUND:
DETAILS: Detonation of an explosive device in baggage compartment. Crashed during emergency landing

08/11/1982
LOCATION: Pacific Ocean 40 from Honolulu
CARRIER: Pan American World Airways FLIGHT:
AIRCRAFT: B-747 REGISTRY:
ABOARD: FATAL: 1 GROUND:
DETAILS: Detonation of an explosive device in the passenger compartment. The aircraft landed safely

06/27/1980 c 21:00
LOCATION: Tyrrhenian Sea, Ustica, Italy
CARRIER: Aero Transporti Italiani FLIGHT: 870
AIRCRAFT: DC-9-15 REGISTRY: I-TIGI
ABOARD: 81 FATAL: 81 GROUND:
DETAILS: Possibly struck by missile. Aircraft broke up and crashed.

01/01/1978 c 20:15
LOCATION: Off Bandra, Maharashtra, India
CARRIER: Air India FLIGHT: 855
AIRCRAFT: B-747-237B REGISTRY: VT-EBD
ABOARD: 213 FATAL: 213 GROUND:
DETAILS: Went into a steep dive and exploded on impact. Malfunction of altitude director indicator.

11/03/1977
LOCATION: Belgrade, Yugoslavia
CARRIER: EI AI FLIGHT:
AIRCRAFT: B-747 REGISTRY:
ABOARD: FATAL: 1 GROUND:
DETAILS: Explosive decompression

10/06/1976 c 13:30

LOCATION: Off Bridgetown, Barbados

CARRIER: Empresa Consolidada Cubana de Aviacion (Cuba) FLIGHT: 455

AIRCRAFT: DC-8-43 REGISTRY: CU-T1201

ABOARD: 73 FATAL: 73 GROUND:

DETAILS: Crashed into Caribbean Sea. Detonation of an explosive device in the aft of the cabin.

01/01/1976 c 05:30

LOCATION: Northeastern Saudi Arabia

CARRIER: Middle East Airlines (Lebanon) FLIGHT: 438

AIRCRAFT: B-720B REGISTRY: OD-AFT

ABOARD: 81 FATAL: 81 GROUND:

DETAILS: Broke-up at FL 370. Detonation of an explosive device the forward cargo compartment.

12/22/1974 c12:30

LOCATION: Maturin, Venezuela

CARRIER: Aerovias Venezolanas SA (Venezuela) FLIGHT: 358

AIRCRAFT: DC-9-14 REGISTRY: YV-CAVM

ABOARD: 77 FATAL: 77 GROUND:

DETAILS: Crashed 5 minutes after takeoff. Unknown cause.

09/15/1974 c 11:00

LOCATION: Phan Rang, Vietnam

CARRIER: Air Vietnam (South Vietnam) FLIGHT: 706

AIRCRAFT: B-727-121C REGISTRY: XV-NJC

ABOARD: 75 FATAL: 75 GROUND:

DETAILS: Hijacked. Detonation of two hand grenades in the passenger compartment.

09/08/1974 c 09:40

LOCATION: Ionian Sea West of Athens, off Kefallinia, Greece

CARRIER: Trans World Airlines FLIGHT: 841

AIRCRAFT: B-707-331B REGISTRY: N8734

ABOARD: 88 FATAL: 88 GROUND:

DETAILS: Went into steep climb then nose-dived into ocean. Detonation of an explosive device in the aft cargo hold

03/03/1974 c 12:40

LOCATION: Bois d' Ermenonville, France

CARRIER: THY (Turkish Air) FLIGHT: 981

AIRCRAFT: DC-10-10 REGISTRY: TC-JAV

ABOARD: 346 FATAL: 346 GROUND:

DETAILS: Crashed shortly after takeoff. Lost improperly latched cargo door. Decompression, damage to controls.

11/03/1973

LOCATION: Over New Mexico

CARRIER: National Airlines FLIGHT:

AIRCRAFT: DC-10 REGISTRY:

ABOARD: 116 FATAL: 1 GROUND:
DETAILS: Overspeeding of starboard engine, engine disintegrated, pieces struck fuselage,
broke window, passenger sucked out.

07/22/1973 22:06
LOCATION: Off Papeete, Tahiti
CARRIER: Pan American World Airways FLIGHT: 816
AIRCRAFT: 707-321B REGISTRY: N417PA
ABOARD: 78 FATAL: 78 GROUND:
DETAILS: Crashed 30 seconds after takeoff into the ocean.

05/18/1973
LOCATION: Southern Siberia, USSR
CARRIER: Aeroflot FLIGHT:
AIRCRAFT: Tupolev Tu-104A REGISTRY:
ABOARD: 81 FATAL: 81 GROUND:
DETAILS: Broke up at FL 300. Detonation of a bomb in the cabin being carried by a
passenger.

06/15/1972 c 14:00
LOCATION: Near Pleiku, Vietnam
CARRIER: Cathay Pacific Airways (Hong Kong) FLIGHT: 700Z
AIRCRAFT: Convair 880M REGISTRY: VR-HFZ
ABOARD: 81 FATAL: 81 GROUND:
DETAILS: Crashed while en route. Detonation of an explosive device in the passenger cabin.

01/26/1972
LOCATION: Near Hermsdorf, Czechoslovakia
CARRIER: JAT FLIGHT:
AIRCRAFT: DC-9-32 REGISTRY: YU-AHT
ABOARD: 28 FATAL: 27 GROUND:
DETAILS: Detonation of bomb in forward cargo hold. Crew member fell 15,000 feet in the
tail section and survived.

02/21/1970
LOCATION: Germany
CARRIER: Swissair FLIGHT:
AIRCRAFT: Convair CV-990-30A-6 REGISTRY: HBICD
ABOARD: 47 FATAL: 47 GROUND:
DETAILS: Detonation of an explosive device in the rear of the plane shortly after takeoff.

10/12/1967 c 07:25
LOCATION: Off south-western Turkey
CARRIER: British European Airways FLIGHT: 284
AIRCRAFT: de Havilland Comet 4B REGISTRY: G-ARCO
ABOARD: 66 FATAL: 66 GROUND:
DETAILS: Broke up at FL290. Detonation of an explosive device in the passenger cabin.

12/08/1963 20:59
LOCATION: Elkton, MD
CARRIER: Pan American World Airways FLIGHT: 214

AIRCRAFT: B-707-121 REGISTRY: N709PA
ABOARD: 81 FATAL: 81 GROUND:
DETAILS: Exploded and crashed while in holding pattern. Lightning induced ignition of fuel tank vapors.

07/28/1963 c 01:50
LOCATION: Off Bandra, Maharashtra, India
CARRIER: United Arab Airlines (Egypt) FLIGHT: 869
AIRCRAFT: de Havilland Comet 4C REGISTRY: SU-ALD
ABOARD: 63 FATAL: 63 GROUND:
DETAILS: Crashed while preparing to land.

05/22/1962 c 21:15
LOCATION: Near Unionville, MO
CARRIER: Contentional Airlines FLIGHT: 11
AIRCRAFT: B-707-124 REGISTRY: N70775
ABOARD: 45 FATAL: 45 GROUND:
DETAILS: Crashed while en route. Detonation of a dynamite bomb in the right rear lavatory.

Unusual Accidents

Captain allowed his children to manipulate the controls.

03/23/1994 00:57
LOCATION: Near Mezhduretshensk, Russia
CARRIER: Russian International Airways FLIGHT: 593
AIRCRAFT: Airbus A310-304
REGISTRY: F-OGQS S/N: 596
ABOARD: 75 FATAL: 75 GROUND:
DETAILS: The aircraft crashed after the captain allowed his child to manipulate the controls of the plane. The pilot's 11 year old daughter and 16 year old son were taking turns in the pilot's seat, flying the plane. While the boy was flying, he put the airliner in a bank of 90 degrees and the nose dropped sharply. Someone pulled back on the yoke to obtain level flight but the plane stalled. Amazingly, rather than the co-pilot in the right hand seat taking over the controls, the captain began to coach his son in recovery techniques. After several stalls and rapid pull-ups the plane went into a spiral descent. In the end the co-pilot initiated a 4.8g pull-up and nearly regained a stable flightpath but the aircraft struck the ground killing all aboard.

Captain almost sucked out of plane

06/10/1990 c 08:20
LOCATION: Oxfordshire, England

CARRIER: British Airways FLIGHT: 5309
 AIRCRAFT: BAC One-Eleven
 REGISTRY: S/N:
 ABOARD: 85 FATAL: 0 GROUND:
 DETAILS: On a flight from Birmingham, England to Malaga, Spain, at FL 230, a large section of windshield fell away from the aircraft. The decompression pulled the captain out from under his seatbelt. Despite trying to hold onto the yoke, the captain was sucked out into the opening. A steward in the cockpit was able to grab hold of his legs. Another steward was able to strap himself into the vacant seat and aid in holding onto the captain's legs. The copilot wearing full restraints made an emergency landing at Southampton. The captain remained half way out of the aircraft for 15 minutes and suffered only frostbite and some fractures. Improper bolts used to replace the windshield two days earlier.

Ran out of fuel while in holding pattern

01/25/1990 21:34
 LOCATION: Cove Neck, New York
 CARRIER: AVIANCA (Colombia) FLIGHT: 052
 AIRCRAFT: Boeing B-707-321B
 REGISTRY: HK 2016 S/N: 19276
 ABOARD: 158 FATAL: 73 GROUND:
 DETAILS: The aircraft was put in a series of extended holding patterns as it approached New York. The crew informed ATC they were running out of fuel but did not declare an emergency and were cleared to land. After a missed approach and during a go-around, the plane ran out of fuel and crashed in a wooded area. The captain speaking very little English and communicating through the first officer at no time declared an emergency. The first officer used the term "we need priority" several times, rather than declaring an emergency. The ATC did not realize the peril of the aircraft. Failure of the crew to properly communicate the emergency situation to the ATC.

Crew preoccupied with listening to a World Cup Soccer match

09/03/1989 c 20:45
 LOCATION: Near Sao Jose do Xingu, Brazil
 CARRIER: VARIG (Brazil) FLIGHT: 254
 AIRCRAFT: Boeing B-737-241
 REGISTRY: PP-VMK S/N: 21006
 ABOARD: 54 FATAL: 13 GROUND:
 DETAILS: The aircraft ran out of fuel due to a navigation error and crashed into the jungle. The crew, preoccupied with listening to a World Cup championship match, flew in the wrong direction. It is

alleged that the pilot led the survivors two days through the jungle to rescue and the first words out of his mouth were "who won".

Nine passengers sucked out of plane and lost at sea

02/24/1989 02:09
LOCATION: Honolulu, Hawaii
CARRIER: United Air Lines FLIGHT: 811
AIRCRAFT: Boeing B-747-122
REGISTRY: N4713U S/N:
ABOARD: 356 FATAL: 9 GROUND:
DETAILS: After leaving Honolulu, on a flight from Los Angeles to Sydney, Australia, the loss of an improperly latched cargo door resulted in explosive decompression and loss of power in the No. 3 and 4 engines. Nine passengers were sucked out of the plane and lost at sea. The plane landed safely.

Both pilots shot by fired airline employee

12/07/1987 16:16
LOCATION: San Luis Obispo, California
CARRIER: Pacific Southwest Airlines FLIGHT: 1771
AIRCRAFT: British Aerospace BAe-146-200
REGISTRY: N350PS S/N: E-2027
ABOARD: 43 FATAL: 43 GROUND:
DETAILS: A fired USAir employee, David Burke, after leaving a goodbye message to friends, shot both pilots. The aircraft went into a steep dive and crashed.

Plane crashed after pilot ignored Ground Proximity Warning System

02/19/1985 09:27
LOCATION: Mt. Oiz, near Durango, Vizcaya, Spain
CARRIER: Iberia Airlines (Spain) FLIGHT: 610
AIRCRAFT: Boeing B-727-256
REGISTRY: EC-DDU S/N: 21777
ABOARD: 148 FATAL: 148 GROUND:
DETAILS: The aircraft crashed into an antenna on Mt. Oiz. Incorrect interpretation of Ground Proximity Warning System (GPWS). The captain was heard shouting "shut up" at the GPWS as it announced "pull up". Overconfidence in altitude alert system. Incorrect interpretation of its warnings.

All four engines failed after flying through volcanic ash

06/24/1982 20:44

LOCATION: Mount Galunggung, Indonesia

CARRIER: British Airways FLIGHT: 009

AIRCRAFT: Boeing B-747

REGISTRY: G-BDXH S/N:

ABOARD: 257 FATAL: 0 GROUND:

DETAILS: The aircraft flew into a plume from a volcanic eruption at 37,000 feet during the night. All engines failed and the windshield lost transparency because of pitting. The first engine was restarted at 12,000 feet, followed by the other three and the plane landed safely at Jakarta.

Aircraft crashed after crew struggled with mentally ill pilot

02/09/1982

LOCATION: Tokyo, Japan

CARRIER: Japan Air Lines FLIGHT:

AIRCRAFT: Douglas DC-8-61

REGISTRY: JA-8061 S/N: 45889

ABOARD: 174 FATAL: 24 GROUND:

DETAILS: The aircraft flew into shallow water after a struggle with a mentally ill pilot. It appears the captain, known to have mental problems, put an engine into reverse while the co-pilot and flight engineer battled to restrain him.

Captain experimented with autothrottle system

11/03/1973 c 16:40

LOCATION: Near Albuquerque, New Mexico

CARRIER: National Airlines FLIGHT: 27

AIRCRAFT: Douglas DC-10-10

REGISTRY: N60NA S/N:

ABOARD: 128 FATAL: 1 GROUND:

DETAILS: Overspeeding of the starboard engine caused the engine to disintegrate. Pieces struck the fuselage, breaking a window, causing rapid explosive decompression and a passenger was sucked out of the plane. The plane landed safely. The captain and flight engineer experimenting with the autothrottle system to see its response to various other instrument settings caused overspeeding of the engine.

Twenty-nine survivors rescued after 2 months in the Andes mountains

10/13/1972

LOCATION: Near San Fernando, Chile

CARRIER: TAMU FLIGHT:

AIRCRAFT: Fairchild-Hiller FH-227D/LCD

REGISTRY: T-571 S/N: 572

ABOARD: 45 FATAL: 29 GROUND:

DETAILS: The flight crashed into Andes mountains. The survivors were not found until 12/22/72. Survivors resorted to cannibalism to stay alive. The book and movie "Alive" is based on this accident.

Crew member fell 33,000 feet and survived

01/26/1972 c 17:00

LOCATION: Near Hermsdorf, Czechoslovakia

CARRIER: JAT Yugoslav Airlines FLIGHT: 364

AIRCRAFT: Douglas DC-9-32

REGISTRY: YU-AHT S/N: 47482

ABOARD: 28 FATAL: 27 GROUND:

DETAILS: The plane crashed after the detonation of bomb in the forward cargo hold. A stewardess fell 33,000 feet in the tail section and although breaking both legs and being paralyzed from the waist down, survived. The bomb was believed to be placed on the plane by a Croatian extremist group.

Co-pilot accidentally deployed spoilers 60 feet off the ground

07/05/1970 08:09

LOCATION: Toronto, Canada

CARRIER: Air Canada FLIGHT: 621

AIRCRAFT: Douglas DC-8-63

REGISTRY: CF-TIW S/N: 46114

ABOARD: 109 FATAL: 109 GROUND:

DETAILS: While landing and approximately 60 feet above the runway, the spoilers were inadvertently deployed causing the aircraft to fall and lose the No. 4 engine. The crew then decided to go-around. The aircraft exploded while attempting the go-around. Inadvertent deployment of spoilers while the aircraft was still in the air by the first officer. Faulty design by allowing the spoiler handle to perform two different unrelated tasks.

Captain suffered heart attack

04/22/1966 20:30

LOCATION: Near Ardmore, Oklahoma

CARRIER: American Flyers Airline FLIGHT:

AIRCRAFT: Lockheed 188C Electra
REGISTRY: N183H S/N: 1136
ABOARD: 98 FATAL: 83 GROUND:
DETAILS: The aircraft crashed into foothills during landing attempt at Ardmore Municipal Airport . Incapacitation of captain with a heart attack during final stages of approach.

Pilot decided to give passengers a view of the mountain

03/05/1966 c 14:15
LOCATION: Near Gotemba City, Mt. Fuji, Japan
CARRIER: British Overseas Airways FLIGHT: 911
AIRCRAFT: Boeing B-707-436
REGISTRY: G-APFE S/N: 17706
ABOARD: 124 FATAL: 124 GROUND:
DETAILS: The aircraft crashed into Mt. Fuji after encountering severe turbulence when the pilot decided to give the passengers a view of the mountain. The aircraft encountered severe clear air turbulence and started to come apart in the air before crashing.

Aircraft crashes after collision with a whistling swan

11/23/1962
LOCATION: Ellicot, Maryland
CARRIER: United Air Lines FLIGHT:
AIRCRAFT: Vickers Viscount 745D
REGISTRY: N7430 S/N: 128
ABOARD: 18 FATAL: 18 GROUND:
DETAILS: The aircraft struck a flock of Whistling Swans at night, at 6,000 ft. One, estimated to be 13 pounds, struck the leading edge of the tail stabilizer, weakening the structure and causing it to detach. The aircraft lost control and crashed.

Son placed bomb aboard aircraft to collect insurance on his mother

11/01/1955 c 19:00
LOCATION: Longmont, Colorado
CARRIER: United Air Lines FLIGHT: 629
AIRCRAFT: Douglas DC-6B
REGISTRY: N37559 S/N: 43538
ABOARD: 44 FATAL: 44 GROUND:
DETAILS: The aircraft crashed 11 minutes after taking off from Denver on a flight to Seattle. Detonation of a bomb in the No. 4 cargo hold, placed by John Graham in his mother's luggage in order to collect \$37,500 in insurance. A delayed flight caused the

bomb to detonate over flat land rather than the mountains as planned. He was executed for the crime.

Husband placed a bomb aboard aircraft to collect insurance on his wife

09/09/1949 10:45

LOCATION: Sault-aux-Cochons, PQ, Canada
CARRIER: Canadian Pacific Airlines FLIGHT:
AIRCRAFT: Douglas DC-3
REGISTRY: CF-CUA S/N: 4518

ABOARD: 23 FATAL: 23 GROUND:

DETAILS: The aircraft disintegrated in flight 40 miles outside of Quebec. Detonation of a dynamite bomb in the forward baggage compartment. Planted by Albert Guay, a jeweler, in a plot to kill his wife, a passenger on the plane. Guay, who assembled the bomb, had his mistress Marguerite Pitre air express the bomb on the aircraft. Ms. Pitre brother, a clockmaker, helped make the timing mechanism. The insurance policy was for 10,000 dollars. All three were hanged for the crime.

Faulty design caused aviation fuel to be sucked into heating vent

10/24/1947

LOCATION: Bryce Canyon, Utah
CARRIER: United Air Lines FLIGHT:
AIRCRAFT: Douglas DC-6
REGISTRY: NC37510 S/N: 42875

ABOARD: 52 FATAL: 52 GROUND:

DETAILS: Fire was reported on board the aircraft before it crashed. An almost identical accident with the same cause occurred on 11/11/47. The flight crew transferred fuel either intentionally or inadvertently from the No. 4 alternate tanks to the No. 3 alternate tanks and failed to stop the transfer process in time to avoid overflowing the No. 3 alternate tank. Gasoline flowed through the No. 3 alternate vent line, out the vent, and was carried back by the slip stream, entering the cabin heater combustion air intake scoop. When the cabin heater came on, an explosion and fire occurred. Design flaw in the aircraft.

Captain intentionally engaged the gust lock in flight

10/08/1947

LOCATION: El Paso, Texas
CARRIER: American Airlines FLIGHT: 311
AIRCRAFT: Douglas DC-4
REGISTRY: NC90432 S/N:

ABOARD: 56 FATAL: 0 GROUND:

DETAILS: The aircraft went into steep dive and pulled out 350 feet from the ground. As an experiment, a captain riding in the jump seat engaged the gust lock in flight. The command pilot rolled the elevator with no response as the jump seat captain disengaged the gust lock causing the aircraft to go into a steep dive, execute part of an outside roll and become inverted. Neither the command nor jump seat captain had seat belts on and accidentally feathered No. 1, 2 and 4 engines. The co-pilot managed to unfeather the props and pull out of the dive.

U.S. Army Air Corps plane crashed into Empire State Building

07/28/1945 9:49

LOCATION: New York, New York

CARRIER: Military FLIGHT:

AIRCRAFT: USAAC B-25 Bomber

REGISTRY: 0577 S/N:

ABOARD: 3 FATAL: 3 GROUND: 11

DETAILS: A U.S. Army Air Force plane crashed into the 79th floor of the Empire State Building in heavy fog. Lt. Col. William Franklin Smith Jr., the pilot, became disoriented while trying to land at Newark Airport. Lt. Smith was told he had a 3 hour wait to land at Newark. Impatient to get his plane on the ground, he falsely declared he had official business at La Guardia Airport with the intention of diverting to Newark as soon as he was cleared. The 12 ton plane smashed a 20 ft. hole in the building. Fuel from the ruptured gas tanks poured out and set two floors ablaze killing 10 people. One engine exited the south side of the building and plunged into a penthouse below.

**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

Appendix I.1 Questions

Source: John Barry Smith

Questions:

There are many questions raised by the realization that four large commercial airliners were not attacked by terrorists detonating bombs but by a common mechanical problem of faulty wires which cause cargo doors to rupture open when they shouldn't. Listed below are some of the informal and unofficial opinions, questions and partial answers that the wiring/cargo door/explosive decompression explanation creates regarding the flights of Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800 and many aircraft in general.

A. How and why does the forward cargo door open in flight?

The United Airlines Flight 811 door open cause was faulty switch or electrical short to door motor to unlatch position which overrode safety locking sectors and door unlatched and opened. Pan Am Flight 103 and United Airlines Flight 811 and Trans World Airlines Flight 800 had midspan latch ruptures and so possibly did Air India Flight 182. Door openings were probably a result of aging aircraft, out of rig door, chafed aging faulty Poly-X wiring, weakened Section 41 area, design weakness of no locking sectors for midspan latches, and only one latch per eight feet of vertical door.

B. How does open door in flight cause nose to come off for Air India Flight 182, Pan Am Flight 103, and Trans World Airlines Flight 800?

The cargo door opens and a huge twenty by thirty foot hole appears in nose on starboard side. Structural members of door and frame are missing, floor beams are fractured, bent, and broken, aircraft direction is askew, flight control surfaces affected, engines damaged, and 300 knots bends the damaged area to starboard and tears nose off within three to five seconds.

C. Why did nose of United Airlines Flight 811 stay on?

Nose of United Airlines Flight 811 may have stayed on because the pilot said he had just come off autopilot and did not fight plane as it gyrated, or plane was younger than others, or the time from door opening to tearing off was 1.5 seconds and allowed the pressurization to be relieved somewhat and six less feet of width of hole was torn off. Essentially, the hole caused by the absent cargo door and skin was much smaller than the other three flights whose forward sections did separate.

D. Air India Flight 182 and Pan Am Flight 103 not a bomb?

Yes, not a bomb for Air India Flight 182 and Pan Am Flight 103 as initial event. The evidence refutes bomb explanation. Those accident investigators years ago did not have the benefit of hindsight, the internet, or several subsequent similar accidents to compare and draw different conclusions.

E. Trans World Airlines Flight 800 not center tank as initial event?

Center tank exploded yes, but after door ruptured/opened, hole appeared in nose, nose torn off in wind, fuselage falling with disintegrating fuel tanks and ignited by fodded and on fire engine number 3 at 7500 feet thereby explaining the Chairman's question at the public hearing, "Why so few bodies burned?" The answer is they were not there to be burned. The nose came off with the passengers inside cabin and descended to ocean alone but not on fire.

F. Is explosive decompression enough to tear nose and forward part of aircraft off?

Explosive decompression is enough to rupture a pressurized hull at weak spot, one latch for eight feet of door, in a weak area, Section 41, but not enough to tear nose off. The ultimate destructive force is the 300 knots of slipstream, more powerful than any wind on earth. If cargo door popped in balloon, the large hole would appear but the nose would stay on. In a tornado, nose comes off within three to five seconds.

G. When forward cargo door opens does it always result in deaths?

No. With United Airlines preflight in 1991 the aft door opened inadvertently and nothing happened because it was on the ground and no pressure differential, so no damage or fatalities. Then Pan Am Flight 125 in 1987 had forward door open partially and plane could not pressurize adequately and turned around and landed, so no damage with slight pressure differential except expense of fuel and risk to life. Then United Airlines Flight 811 happened with smaller hole and 1.5 second delay in opening and nine dead with larger pressure differential. Then in October, 2000, another Boeing 747 had a forward cargo door open inadvertently on the ground when the circuit breaker was pushed in but no fatalities. Pan Am Flight 103, Air India Flight 182, and Trans World Airlines Flight 800 had explosive decompression occur up high with maximum differential and door ruptured and shattered and took skin to the left and right and above with it exposing huge hole and forward part of aircraft came off and all aboard died. When the forward cargo door ruptures or fully opens or partially opens, different consequences occur from minor to severe depending on speed at which door ruptures/opens and pressure differential which depends on altitude.

H. Is there a conspiracy to keep cargo door explanation quiet?

There is no conspiracy, no plot, no coverup by agencies involved with the cargo door explanation:

1. No conspiracy of Sikh terrorists named Singh to put a bomb on Air India Flight 182; the door ruptured in flight.
2. No conspiracy of Libyan terrorists or whoever to put a bomb on Pan Am Flight 103; the door ruptured in flight.
3. No conspiracy to detonate a bomb on United Airlines Flight 811 as the passengers thought, as the crew thought and told the tower who told the Coast Guard and crash crews on the ground as they prepared for a wounded 747 coming in after a bomb blast; the door ruptured in flight.
4. No conspiracy to put a bomb on Trans World Airlines Flight 800; the door ruptured in flight.
5. No conspiracy of terrorists to shoot a missile.
6. No coverup by US Navy to hide accidental shootdown.
7. No coverup by Boeing, NTSB, FAA, or TWA, TSB, RCMP, Scotland Yard, or AAIB who are hiding the knowledge the doors ruptured in flight.

I. Why the huge hole on starboard side in cargo door area while port side smooth?

That's where the forward cargo door is located on all the aircraft, forward of the wing on the starboard side. The rectangular shattered zone around the forward cargo door is apparent on all the wreckage reconstruction photographs and drawings. The unilateral damage on TWA Flight 800 refutes the center tank explosion as the initial event.

J. Are passengers at risk right now?

Yes, all passengers currently flying in early model Boeing 747s with Poly X wiring are at risk of the faulty wiring shorting on the door unlatch motor causing the ruptured opening of the midspan latches of the cargo door leading to explosive decompression and fatalities. The fault has unofficially occurred in 1985, 1987, 1988, 1989, 1991, 1996 and 2000.

K. What is the sudden loud sound on the CVR on all four aircraft at the initial event time of the inflight breakup?

The sound is the rush of air molecules to the outside to equalize the high pressure air in the cabin with the low pressure air outside at altitude. Explosive decompression is a very loud event.

L. Why the almost immediate power cut to the recorders?

The main equipment compartment (MEC) is immediately adjacent and in front of the forward cargo compartment. The MEC has the wiring power to the recorders and the explosion of decompression nearby cuts off power immediately.

M. Why the right side inflight airframe damage?

The starboard (right) side is where the forward cargo door opens in flight and material from inside the compartment and cabin above are ejected into the slipstream. Engine number three and the right horizontal stabilizer are close to and aft of the forward cargo compartment. The objects are ingested into the nearby engine number three, strike the leading edge of the right wing, and continue aft and strike the right horizontal stabilizer. The port side is relatively unscathed from inflight debris.

N. Why the shattered area around the forward cargo door?

When the explosion of decompression occurs, the door is flung open if all the latches unlock and shattered if the bottom eight latches hold but rupture at the midspan latches. The top part of the door opens outward and upward and away taking much fuselage skin above the door with it.

O. Why the streak for Trans World Airlines Flight 800?

The streak is the reflection of the evening sun of shiny metal skin from the forward cargo door area coming off in flight during the explosive decompression and seen by ground observers in darkness to the east as the objects quickly decelerate from 300 knots in a horizontal direction to straight down from 13700 feet.

P. What is the ignition source for the center fuel tank explosion of Trans World Airlines Flight 800?

The ignition source for the center fuel tank explosion is the on fire engine number three which ingested foreign objects from the forward cargo compartment after the ruptured opening of the forward cargo door. The falling and disintegrating fuselage and fuel tanks were ignited by the fiery exhaust and caused the explosion well after the initial event.

Q. Why do the authorities think Pan Am 103 was a bomb explosion?

There was a relatively mild, directed discharge of a shotgun type weapon in the

forward cargo compartment after the explosive decompression. This discharge put a small shatter zone of 20 inches into the skin on the port side of the compartment. The authorities call this event the initial event of a bomb explosion. A Boeing 747 can tolerate a 20 inch hole in its fuselage and in fact has been designed to withstand such a hole of that size and larger. United Airlines Flight 811 showed that a Boeing 747 can safely withstand a ten foot by twenty foot hole in the fuselage and land safely. Bombs are not mild, are spherical, would make a bomb sound on the CVR, and leave much other evidence than a small hole.

R. Why do the authorities think Air India Flight 182 was a bomb explosion?

Air India Flight 182 had a catastrophic inflight breakup that looked like a bomb had gone off inside it. An explosive decompression mimics a bomb explosion. There was evidence of an explosion. At the time there was no other reasonable explanation for such an explosive decompression for a Boeing 747 except for a bomb or to leave the cause unstated. The finding of a bomb explosion for Air India Flight 182 was based on two erroneous assumptions by the Indians: an explosive decompression could not abruptly turn off the electrical supply to the recorders and the floor panels separated upward from a exploding force from below.

S. How can the experts and the public be so wrong?

Experts and laypersons below:

1. police
2. aircraft accident investigators
3. media
4. government
5. manufacturer
6. attorneys, plaintiffs, defendants, and judges
7. airlines
8. flightcrews
9. passengers.

This is a political and human nature question; the best I can do to explain it is as follows: Experts are often wrong; they are human. In the case of the wiring/cargo door/explosive decompression for four Boeing 747 accidents:

The experts were all partially right and partially wrong, some more than others. The good ones try to find their errors, correct them and continue on; however, it is understandable that the not so good experts and laypersons are reluctant to investigate alternative probable causes for fatal aircraft accidents if that path leads to unpleasant truths with a result:

For the law enforcement authorities to have their budgets cut and staff reduced instead of increased to fight terrorist activities,

For accident investigators who have previously made conclusions about causes that are now refuted and whose credibility would now be in jeopardy and threaten their reputations,

For the media to have a boring mechanical story that has happened before and was supposed to have been fixed instead of an exciting spy conspiracy story,

For the government who has oversight of all to find out it overlooked and allowed noncompliance of regulations to occur,

For the manufacturer to discover most of the thousands of airplanes it constructed have severe design problems of outward opening non plug cargo doors, inadequate midspan latches, and faulty wiring installed.

For attorneys, plaintiffs, defendants, and judges who have caused the transfer of hundreds of millions of dollars in lawsuits to discover it was decided on factual errors,

For the airlines to find out they may have not kept their airframes maintained properly,

For the flightcrews who do not want to believe their aircraft can come apart at any second and there is nothing they can do about it,

For the passengers who want to be persuaded there is no danger in flying and insist on being reassured that any problems have been fixed, their ticket prices are low, and they have their baggage with them.

All parties are acting in their perceived best interest and believing in wishful thinking. They are not objective. In this particular case, when Boeing 747s are breaking apart in flight, there is an understandable perceived best interest by all parties to believe they are not responsible for the accidents and the fatalities. By having the blame shifted to outside forces such as terrorists, most parties are absolved of guilt. The parties, law enforcement and security, responsible for allowing the 'bomb' to be put aboard are rewarded with higher staffs and budgets. The only losers with the 'bomb' explanation are the ones accused of putting it there and they never dispute the 'bomb' but deny they put it there.

The electrical problem in airliners is difficult to detect because the symptoms are treated instead of the cause. Faulty wiring and switches do more than cause cargo doors to open in flight; they cause yaw dampers to swing back and forth, they cause autopilots to disconnect or act strange, and they often cause fires. When cargo doors ruptured open in flight over a period of eleven years in four airlines in four airports in three countries, investigation jurisdictions were spread out over distance and time. Each agency looked at the sole tree and did not see the forest of four trees.

There are built in protection beliefs when a Boeing 747 crashes. The manufacturer contributes to the welfare and salaries to tens of thousands of employees and indeed, the whole northwest of the United States derives much support from Boeing. If the company were to be put in jeopardy because of manufacturing errors and be the subject of lawsuits, literally millions of citizens would be concerned. All parties including the government, the media, the investigating agencies, and the legal system do not want the company to be in danger and instinctively, although not conspiratorially, act together to protect that company. If any sort of plausible explanation that exonerates the company exists, that explanation will be eagerly sought and agreed with. That sudden agreement explains why the 'bomb' explanation for all four aircraft was discussed within hours of the discovery of the accident and immediately accepted as a working hypothesis. In every report the 'bomb' explanation is the one most quickly sought to be confirmed by the authorities. Incredible lengths were taken in time and money to confirm the 'bomb' explosion.

An explosion by explosive decompression caused by an inadvertently opened forward cargo door inflight mimics a 'bomb' explosion in many ways. Passengers get hit by flying debris, metal is petaled outwards, recorders pick up a loud noise, wings and tails get struck by pieces of skin, engines suck in pieces of metal, and the aircraft can disintegrate and catch on fire as it falls. Tangible evidence of a bomb is hard to find as the bomb explodes and distributes the timer, fuze, and container far and wide. It looks at first glance as if a bomb had gone off.

It is understandable how all concerned parties are eager to accept the plausible and absolving 'bomb' explanation and very, very reluctant to investigate the implicating wiring/cargo door/explosive decompression explanation for the four Boeing 747 accidents that suffered breakups in flight.

It is also understandable that a person motivated by actually being in a sudden, night, fiery, fatal, jet airplane crash and surviving, although the pilot was killed, takes great effort to prevent it from happening to others. Because that person is also being completely independent of

all the other parties he can objectively evaluate the separate accidents to see the pattern and thus the common probable cause for all. That fatal accident was in 1967 and that person is the author of this report.

It is only when the evidence becomes overwhelming, incontrovertible, and irrefutable that an alternative explanation to a bomb is even considered seriously and when that new explanation reveals a clear and present hazard to the flying public, then the parties will reluctantly reexamine the evidence to conclude that it was not the lesser evil of 'bomb' but the greater evil of a mechanical problem, a design problem, an oversight problem, that was supposed to have been fixed, but wasn't, and it could happen again.

T. Can you describe in layperson's terms what happens?

A layperson's explanation for the destruction of Pan Am Flight 103 relies on basic science and common sense and might go like this:

Why do airplanes fly?

They fly because of lift which exceeds the drag. Common sense tells us that cutting anything such as butter with a knife causes friction. Friction also slows things down when an object moves through the air and creates heat. Friction is drag.

Lift is created when the air flowing over the top of the wing takes a longer distance than the wind flowing over the bottom of the wing. This causes a pressure differential between the top and bottom of the wing. The wing is sucked upwards into the lower pressure air on top of the wing.

The wing must be moving through the air. This can be done in many ways but the usual way is for an engine to make the wing move forward by expelling gases to the rear. This powerful thrusting overcomes the friction of the drag and moves the wing through the air which creates the lift and the airplane flies.

Why do balloons rupture?

Balloons rupture when the compressed higher pressure inside air breaks through the balloon material and to suddenly equalize the pressure to the uncompressed lower pressure outside air. It happens so fast it's called an explosion. The rupture cause can occur from within or from the outside of the balloon. If the balloon material is just stretched too far, the rupture cause is on the surface. The outside air pressure is less as the balloon goes higher making the inside air pressure greater and greater.

Regardless of the cause of the rupture, the material of the balloon is shredded, torn, and frayed from the outward force. If the balloon is placed under deep water then the reverse is true and the balloon will implode and the material will be shredded, torn, and frayed from an inward force. In this regard, a submarine is opposite from an airplane. The higher an airplane goes, the higher the pressure inside; the lower a submarine goes, the higher the pressure outside. An airplane can explode while a submarine can implode. Airplane plug type doors get tighter as the plane goes higher and submarine plug type door get tighter as the sub goes deeper.

What makes the sudden loud pop sound?

The pop is the noise of the suddenly rushing outward air molecules rubbing against the other slower moving air molecules. Heat and noise is created.

What evidence is there of the balloon pop in air?

A sudden loud sound.

Torn, shredded, and frayed material.

Any inside material of the balloon moving to the outside.

What is lightning?

Lightning is the equalizing of a electrical potential from one charged area to a differently charged area. It is similar to a balloon pop except the movement is with electrons instead of air molecules. Lightning causes fires by the intense heat created by this equalizing of electron pressure differential.

Wiring conducts this discharge of electrons in directions to make things like motors move or stop moving. When the wiring is not insulated the electrons in the bare wire will seek out a different way to flow to equalize the different energy potential created by the generators. and as a result, fires may start or motors may turn on when they are not supposed to.

Compressed air in a balloon and a full battery are similar in that they both have energy stored up that seeks to discharge if given a chance.

Why does a hand move backward when it is stuck out the window and turned flat against the wind?

Air has weight. It may be invisible but it is real. When your hand is thin to the wind, the resistance of your hand moving through the air molecules is less but when you turn your hand flat against the wind, the extra area of your wide hand gives a greater resistance to the wind and the weight of the wind force is increased to push your hand back. If the wind force is very powerful it can push your hand back so hard it can break it. The highest wind on earth exists in Force Five Tornadoes with wind speed up to 250 miles per hour. These winds tear roofs off houses, pick up trucks and spin them around, and toss cows for long distances.

Why did Pan Am Flight 103 crash?

For Pan Am Flight 103, the huge airplane was able to fly because of its wings which gave lift as the plane moved through the air powered by the jet engines which created thrust which overcame the friction of the drag of the airframe on the air molecules.

As the plane flew higher, the air inside become compressed relative to the outside air. The inside air was actually less compressed than the air on the ground, but relative to the outside very low pressure air at altitude, the inside air was highly compressed thus creating a large pressure differential. It was like a balloon being expanded.

The balloon of the fuselage of Pan Am Flight 103 got bigger and bigger. It actually expanded from the inside out as the air molecules inside tried to get outside to the less dense air to equalize the pressure differential. The air molecules inside pressed against every inch of the fuselage at the rivets, the windows, the doors, the hinges, the latches, and the skin itself.

Usually Pan Am Flight 103 would later descend and the process would be reversed and the pressure differential would be reduced until landing when the outside and inside pressure would be

equal and the balloon of the fuselage would shrink back to normal. This continual blowing up and letting out the air in the balloon of the fuselage put wear and tear on all the fitting, rivets, windows, hinges, latches, and doors in the fuselage frame.

Pan Am Flight 103 was flying normally very high up with the pressure differential at its maximum, and the balloon was at its most expanded with the inside air molecules pressing the hardest on the inside of the fuselage which included the cockpit, the passenger cabin, the lavatories, and the cargo compartments.

Suddenly, lightning struck in a small way when the electrons of electricity which were normally blocked on their way to a motor found another way to get there because the blocking insulation cracked and exposed the bare wire which touched another discharge path. The lightning flowed to a motor which turned on and did what it was designed to do when it received electricity, turn some wheels called cams which encircled some pins in a device called a latch. In this case the cams turned in the direction to allow the latch of a forward cargo door to unlock. As the latch became just so slightly unlocked, the huge internal compressed air pressure burst the entire cargo door open at the weakest point, the midspan latches that held a long eight foot stretch of sliced fuselage together and had no safety locks to prevent what was accidentally happening.

The balloon of Pan Am Flight 103 popped. A sudden loud sound was produced and heard by everyone on board as the compressed air rushed out of the balloon of the fuselage and forward cargo compartment into the outside air in front of the engines on the right side of the airplane. The rupture area of the cargo door became shattered, torn, and frayed from the outward force of the air molecules. The pop of the balloon was so violent it disrupted all the electricity in a nearby equipment compartment and turned off the power to the data recorders. Material from inside the cabin and cargo compartment was ejected outward into engines and against the right wing and rear stabilizers.

The explosion of the pop of the fuselage is called an explosive decompression. The force is so great it curls, pits, craters, bends, tears metal into fragments and affects the actual atom makeup of the metal. The hole the explosive decompression caused when the large door was ruptured and tore outward, upward, and away was about twenty feet wide and thirty feet tall.

If Pan Am Flight 103 had not been moving the damage may have remained as it was, a big hole in the right side of the nose with a lot of stuff from the cabin and cargo compartment ejected and missing. However, there was 300 knots, about 330 miles per hour, of wind force on the nose of the airplane. The nose shuddered because the sides, the bottom, and top of the fuselage which had strong beams to hold it together were all bent, twisted, and broken.

The enormous wind force of the weight of the fast moving air molecules on the weakened forward part of Pan Am Flight 103 tore it off to the right. The jagged blunt end of the torn off nose was too much drag for the engines to overcome. The airplane slowed down. The airplane could not fly because there was not enough lift from the wings.

The aircraft broke in two and fell to the sea, coming apart in many pieces as it disintegrated from the unusual forces applied from all directions.

The passengers inside Pan Am Flight 103 who were now outside falling would die because the human body can not withstand the force of striking very dense water molecules at a high speed.

To sum up: The surface of the inflated fuselage popped when the lightning of the electricity caused

a motor to turn on which allowed a hole to appear in the forward cargo door and allowed the compressed air molecules to escape outside to the less compressed air molecules. The escape was so sudden as to shatter and tear the surface of the inflated fuselage at the forward cargo door. The aircraft came apart when the extremely fast moving air molecules pressed so hard against the weakened forward part as to break it in two. The passengers died because they struck the water too fast for the water to make a hole for them.

The technical term is the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression at the midspan latches. The door opening was attributed to faulty wiring or switch in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure.

U. Why have the defense of the accused not used the shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup explanation as a defense?

The defense teams have always stated it was a bomb that went off and destroyed the aircraft and passengers but their clients did not plant the bomb. The defense has never argued there was no bomb, no crime, and therefore no criminals. The defense attorneys are criminal attorneys who know who banks are robbed but not how or why airplanes crash.

Below from Lockerbie Judgment: "It is not disputed, and was amply proved, that the cause of the disaster was indeed the explosion of a device within the aircraft." The defense never disputed the cause of the airplane crash their clients were accused of causing and the judicial court accepted the flimsy evidence of a bomb explosion without question from the experts.

V. Could the twenty inch hole on the port side cause the forward section to separate?

Even if an explosion or a shotgun fired, there is still only a twenty inch shatter hole which is not big enough to cause the forward section to come off because the airframe is designed to withstand such a sized hole when hull is pressurized and, indeed, a Boeing 747, United Airlines Flight 811, successfully withstood a much larger hole in the same area of the aircraft on the starboard side.

W. Could the firing of a shotgun or explosion on the port side cause the starboard side cargo door area to rupture outward?

Any firing of a weapon or small directed explosion which caused a twenty inch hole on the port side would have instantly decreased internal pressure of the hull which was impinging on the forward cargo door making it less likely that door area would rupture in flight at initial event time. The evidence of the recovered wreckage and illustrated by the wreckage distribution charts in Appendix B of AAIB AAR 2/90 shows that the forward cargo door area did suffer a large and catastrophic hull rupture at initial event time.

The pressure waves of the relatively mild explosion did not destroy a nearby fiberglass baggage container and were thus unlikely to blow out a strengthened side of a fuselage. The firing of a weapon in the forward cargo hold was very unlikely to have caused the extensive damage on the starboard side.

X. Was a weapon found in the wreckage that might have caused the mild directed blast against the port side fuselage which might have been a rather large shotgun?

A weapon may have been recovered in the wreckage, logged in, and therefore the wreckage database must be searched for any recovered weapons.

Y. Were there any passengers on board who might have been reasonably expected to carry weapons in their baggage?

There may have been experts in firearms, or weapon salesmen, or gun collectors on board who might have put their products in their baggage. The passenger manifest needs to be checked for such persons.

Z. Are there any other possible explanations for the mild directed explosion on the port side of the forward baggage compartment for Pan Am Flight 103?

Diplomatic pouches are often carried on international flights which do not go through security checks. A pouch may have held a weapon or have been booby trapped to explode into the face of the unauthorized person attempting to open it. Antique guns are often shipped by air. Flares and blasting caps might have been inadvertently ignited. There are several reasonable explanations that offer alternative to a bomb causing the mild directed explosion in the forward baggage compartment on the port side.

AA. Since the opinion was given by the AAIB of a rather large shotgun, is it possible for a further description?

Based upon the evidence recovered, it should be possible for the FBI or Scotland Yard to determine the caliber, the type of powder, and the type and model of the weapon that would have caused the mild directed blast that exited one container, struck another and caused a twenty inch hole in the fuselage leaving soot and pitted metal behind.

AB. How can the problems revealed be fixed?

1. Faulty Poly X wiring can be fixed by:
1. Turning off all unnecessary electrical circuits.
2. Removing all unnecessary wiring. Only that wiring which is needed for safe aircraft flight is required to be wired such as engines, communications, navigation, and cockpit instruments.

3. All other electrical needs can be wireless or battery driven.

2. Rupturing open cargo doors can be fixed by:

1. Making the doors plug type, or,
2. Barring the doors mechanically so that they can never open, and,
3. Entering cargo compartments from inside the hull to store items.

AC. Are the repairs suggested economically feasible?

It is in the best interests of the airlines, the manufacturer, the government, and the passengers and flight crews that all known hazards to flight safety be removed as soon as possible. Flying is dangerous and all hazards can not be removed but those that are discovered must be corrected. A safer airplane is a best selling airplane. A best selling airplane is a popular airplane. A popular airplane creates secure jobs.

AD. Why has the author pursued this issue of wiring/cargo door/explosive decompression events for over a decade?

The best answer I can give to that is that my life was literally within two seconds of ending but was saved by the unselfish action of my pilot who in a time of stress with a disabled aircraft took the time to tell me to 'eject' which I did unquestionably and lived by the two seconds I had while he died because of the two seconds he did not have. Because I survived one, I believe I am repaying a moral debt to prevent others from dying in a sudden night fiery fatal jet airplane crash.

**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

Appendix J Bruntingthorpe



A dramatic test proves that simple improvements can checkmate bomb-wielding terrorists.

BY JIM WILSON

In less than a minute, bombs will shower England's Bruntingthorpe Airfield with the jagged remains of a Boeing 747 jumbo jet.

"We cannot tell you their exact size and location," says Richard Wright, a spokesman for the Civil Aviation Authority (CAA), which is sponsoring one of the most dramatic experiments in aviation history. They are about to blow up a retired Air France 747. If the experiment plays out as expected, the CAA will have solid proof that simple improvements in baggage container and cargo bay design can minimize the damage of terrorist bombs, like the one that downed Pan Am Flight 103 over Lockerbie, Scotland, in December 1988.

Wright's colleague, Rory Martin, suggests I pay especially close attention to the rear of the doomed plane. "We concentrated on the cargo bay," he explains. "We want to know how the explosions work, how structures fail." To this end, one of the four bombs has been placed inside a standard baggage container, close to an unprotected section of fuselage.

Taking Martin's advice, I aim my binoculars at a spot between the tail and the wing as I listen to the final countdown. Three, two, one . . . Four explosions detonate simultaneously. Inside the aft cargo bay, the pressure wave from one of the blasts has blown through a standard baggage container as if it were just wrapping paper. Unimpeded, these rapidly expanding, high-temperature gases hammer into the fuselage.

To make the experiment more realistic, the interior of the plane was pressurized. Creating just the right amount of pressure proved to be one of the day's most difficult challenges, and it caused several holds in the countdown. During one of these delays, Chris Peel, a top British structures

and materials expert, told me why getting the pressurization right was so important to the outcome of the experiment. "If the aircraft is unpressurized, small cracks will produce minor damage. Catastrophic damage occurs when the pressure difference amplifies the damage, causing the cracks to run," he says.

These amplifying effects soon become apparent. The explosion creates a jagged tear that races forward to the wing, makes a 90° turn and then splits the skin along a line of rivets around the fuselage. The tail section slumps down on the runway. A cloud of fire-extinguishing carbon dioxide gas is released to smother any secondary fires that may have erupted.

After this gas has dispersed, I am allowed a closeup look at the damage. "The standard container was virtually transparent to the explosion," says Peel. A container hardened with a material similar to that used in bulletproof vests and placed near the front of the forward cargo bay (see diagram on opposite page) appears to have fully contained the force of the bomb planted inside.

A second standard 5 x 5 x 5-ft. container also has been demolished, but there is little visible evidence of this outside of the plane. A 15-ft. "bulletproof" panel placed against the fuselage as a sort of shock absorber apparently has performed as advertised. There is likewise no evidence of damage to the fuselage next to a standard baggage container that has been modified by the addition of an 8-in. foam liner.

It will be late fall before the Defence Evaluation and Research Agency, which conducted the experiment for the CAA, issues its final report. But a cursory inspection shows that technology for blunting terror's threat is at hand. "If you put all the changes together," suggests Martin, "they make a good system."

By Lauren Terrazano
Staff Writer

A CENTER FUEL tank blown up by TWA Flight 800 investigators shows damage patterns unlike anything found on the fuel tank of the downed plane, according to early test results -- a development that could finally rule out the possibility that any explosive charge destroyed the plane, sources said.

Since last spring, officials had said they were close to eliminating the bomb and missile theories that had long dominated speculation about the crash's cause. But FBI investigators have been reluctant to be definitive, saying they wanted to re-analyze the wreckage and await the results of more tests.

The test results, from several detonations of a Boeing 747 tank in Bruntingthorpe, England, last month, brought investigators one step closer to dropping the idea of a small, "shaped charge" placed on or near the Flight 800 tank -- the only possibility left of a bomb, because of the lack of other evidence.

"Very small amounts of explosives left very distinctive marks, unlike anything we've seen on the plane," said one investigative source, speaking of the recent tests. "Even the small amounts [of explosives] left distinctive signatures on the structures, so if a small bomb had gone off, it clearly would leave a signature."

Five other theories of ignition remain, including a dud missile or other object piercing the plane's skin and four mechanical scenarios: a static charge within the tank, a faulty scavenge pump, corroded fuel probes and damaged wiring in the right wing.

Investigators have determined the blast originated in the nearly empty 12,890-gallon tank, igniting fuel air vapors in an explosion that tore the plane apart, killing all 230 people aboard. The actual ignition source remains a mystery.

The National Transportation Safety Board has directed hundreds of tests in laboratories around the world to study potential factors in the explosion.

In October, investigators plan to blow up portions of a center fuel tank in Denver in conjunction with work being done on fuel volatility with the California Institute of Technology. Investigators

hope to determine the direction in which flame travels through the tank's different compartments. The testing could help investigators confirm the exact point of ignition within the tank.

Full-scale explosions will follow "within six months" said NTSB spokesman Peter Goelz, adding that results of the Denver tests would not likely be made available before the public hearings planned on the crash in December. "So little is known about the flammability of Jet A fuel that we need to continue and expand our tests," Goelz said.

The NTSB said the results of the Bruntingthorpe tests are still being analyzed and would not be released until the hearing.

In those tests, investigators set off series of small explosions at various points on the tank, trying to determine impacts that could be compared to TWA Flight 800's reconstructed fuel tank. A final explosion included filling the tank with propane to see how it broke apart.

The board also measured the data from the explosions on a cockpit voice recorder to compare to the recording from TWA Flight 800. The data are still being analyzed, but investigators said they weren't hopeful about the comparisons because the test plane used in Bruntingthorpe wasn't pressurized like Flight 800 was, and it would therefore emit a different sound signature.

A parallel criminal investigation of the crash is continuing, and FBI Assistant Director James Kallstrom told victims' families July 19 that the inquiry could wrap up within 60 to 90 days.

The agency said yesterday it would not comment on the Bruntingthorpe tests. "Because the investigation is ongoing, we're not discussing any test results that may have been completed," said FBI spokesman Joseph Valiquette.

May 17, 1997

BRUNTINGTHORPE, England (Reuter) --

Scientists Saturday blew up an old jumbo jet in their quest for ways to make planes safer from terrorist attack.

The giant jet was almost split in two by the blasts, which left the tail section lying crumpled on the ground.

The test, sponsored by Britain's Civil Aviation Authority (CAA) and the U.S. Federal Aviation Administration (FAA), was designed to find new ways of making aircraft more bomb-resistant.

Four bombs were exploded inside the pressurized cargo hold of a Boeing 747 in the former U.S. Air Force Strategic Air Command base at Bruntingthorpe, Leicester, about 100 miles north of London.

In 1988, 270 people were killed when a bomb destroyed a Pan Am 747 which crashed to the earth in Lockerbie, Scotland. In 1989, another 171 perished when a bomb brought down a French UTA DC-10 airliner over Niger.

The experiment, part of a five-year \$5 million research program to improve aircraft structures, was carried out by Britain's Defense Evaluation Research Agency (DERA), a wing of the Ministry of Defense.

Two explosions were designed to test two new types of baggage containers and a third tested a body-armor type of protective material in the cargo hold.

A fourth demonstrated the impact of bombs against unprotected structures, CAA spokesman Richard Wright said.

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Appendix K Weapon firings:

April 26, 2000 Gun goes off in bag being loaded into jet No one hurt when bullet lodges in diaper bag under seat Associated Press - PORTLAND _ A high-powered handgun went off in the baggage compartment of an Alaska Airlines jetliner on the tarmac at Portland International Airport, sending a bullet into the passenger compartment within inches of passengers' feet. Nobody was injured.

The .357-caliber Ruger discharged in a suitcase as it was being thrown into the cargo hold of a Boeing 737 being loaded Monday night for a flight to Anchorage, Alaska, said Port of Portland spokesman Doug Roberts. The bullet went through the floor of the passenger compartment and into a diaper bag under a seat, said airport police officer Michael Brant. It tore through a baby's picture album and lodged inside a baby changing pad. Passenger Grant Johnston, who had placed the diaper bag under the seat, told KGW-TV that he had heard a loud noise at his feet and notified a flight attendant. "That was really scary," Johnston said. "It was a little too close. It was right under our feet. It was just a few inches away, and it could have hurt somebody." The crew and 85 of the 86 passengers on Flight 101 were transferred to another plane while maintenance workers checked the jet for damage. One passenger, Betty Jean Smith, 66, of Eagle River, Alaska, was charged with reckless endangerment and concealing a weapon without a permit. She was released to relatives in Vancouver, Wash. The gun was one of two in her bag. The other gun also was loaded. "She didn't know anything about firearms," Brant said. "She brought them here for her son. He didn't want them so she was bringing them home." Regulations require that passengers declare guns when they have packed them in checked luggage; regulations also require that those guns be unloaded, Roberts said. If the gun had fired during the flight at a high altitude and the bullet had made a large hole in a window, the aircraft would have experienced rapid decompression, said Alaska Airlines spokesman Bill MacKay. However, he said, if the bullet had penetrated the plane's outer skin, the hole would have been smaller and there would have been no threat of rapid decompression.

12:14 PM ET 07/01/98 FAA warns air travelers on carrying fireworks

WASHINGTON (Reuters) - Fireworks found in airline passengers' bags can result in fines of up to \$250,000 and five years in prison, the Federal Aviation Administration reminded travelers Wednesday.

FAA said the illegal transport of fireworks in checked or carry-on bags was a particular problem around the July 4 Independence Day holiday.

"Fireworks of all shapes and sizes - from Roman candles to the smallest poppers and sparklers - are strictly prohibited from passengers' bags," FAA civil aviation security official Cathal Flynn said in a statement.

"Not only would you be risking fines or even criminal prosecution ... you would endanger yourself and everyone else on board," Flynn said.

Concern about hazardous cargo was heightened by the 1996 ValuJet crash into the Florida Everglades after a fire broke out in its cargo hold just after takeoff from Miami. All 110 people on board were killed.

A Frenchman whose smoking suitcase was pulled from a baggage cart at Miami International Airport recently was fined \$3,000 for illegally transporting boating safety flares.

^REUTERS@

*** Flare ignites in luggage at Miami airport A smoking suitcase led U.S. authorities to arrest a French tour operator for transporting hazardous materials, possibly averting an air disaster, The Miami Herald reported. Leo Guy Cauvin, 55, a French citizen living in Taunusstein, Germany, was charged with transporting hazardous materials after a flare gun apparently ignited in his suitcase. His bond was set at \$10,000 in a court appearance Thursday. Baggage handlers noticed smoke billowing from the suitcase sitting on a baggage cart about to be taken on a US Airways flight to Philadelphia. The flare that ignited was one of five boating-type safety flares in the suitcase, which also contained clothing. See 01:49 PM ET 06/05/98

Flare ignites in suitcase at Miami airport

(Adds investigators' quotes, details)

By Jane Sutton

MIAMI (Reuters) - A flare gun ignited inside a French tour operator's suitcase only minutes before he was to board a flight at Miami International Airport and could have caused a major air disaster, investigators said Friday.

Baggage handlers noticed smoke billowing from the suitcase sitting on a baggage cart about to be taken to a US Airways flight to Philadelphia on Wednesday.

Leo Guy Cauvin, 55, a French citizen living in Taunusstein, Germany, was arrested and charged with transporting hazardous materials. His bond was set at \$10,000 in a court appearance Thursday and he remained in jail Friday.

"Had that thing gone off in the cargo hold in the suitcase, everyone on that flight would have perished," Assistant U.S. Attorney Wilfredo Fernandez said.

"We would have had another ValuJet," he said, referring to a cargo fire that caused a ValuJet flight to plunge into the Florida Everglades in 1996, killing all 110 people aboard.

Flares of that type generate their own oxygen and burn at 2,000 degrees Fahrenheit, Fernandez said.

The Department of Transportation and the Federal Aviation Administration's Office of Civil Aviation Security are investigating the incident, DOT spokesman Jeff Nelligan said.

A US Airways spokesman, Rick Weintraub, said the carrier will cooperate fully with the investigation.

The bag had been checked through security and tagged to a connecting flight to Frankfurt. The flare that ignited was one of five boating-type safety flares in the suitcase, which also contained clothing. Three of the flares were loaded into a flare gun, ready to fire, Fernandez said.

He said investigators were still trying to determine what caused the flare gun to go off and whether the suitcase had been X-rayed. Inspectors also found pepper spray in Cauvin's carry-on luggage, the arrest report said.

Cauvin's attorney, Paul McKenna, said Cauvin is an avid scuba diver who had been visiting the Florida Keys. Cauvin acknowledged to police that he had packed the flares in his suitcase but said he had thought they could not go off.

The incident illustrates a growing problem with passengers loading hazardous materials into their luggage, Fernandez said. In a pending case in Fort Lauderdale, a woman was charged with packing a plastic jug of gasoline and a small motorbike into luggage she intended to check. It was discovered when the gasoline container leaked, he said.

"It's not like it's a flurry of cases but it's the second one in the last three months," Fernandez said. "I don't know if it's ignorance, if it's negligence. It's certainly criminal."

The U.S. House Transportation and Infrastructure Subcommittee on Aviation is studying how to improve airline security and whether all baggage must be X-rayed, Nelligan said.

"The issue is still open. The machines that they use for this are pretty slow," he said. A recent hearing before the subcommittee focused on questions such as "Should we look at all bags, both checked and carry-on? How long would this take?" he said. ^REUTERS@

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Appendix L: Air Accidents Investigation Branch
Aircraft Accident Report No 2/90 (EW/C1094)

<http://www.open.gov.uk/aaib/n739pa.htm>

Air Accidents Investigation Branch
Aircraft Accident Report No 2/90 (EW/C1094)

Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988

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Appendix G Mach stem shock wave effects

Figure G-1

Operator: Pan American World Airways
 Aircraft Type: Boeing 747-121
 Nationality: United States of America
 Registration: N 739 PA
 Place of Accident Lockerbie, Dumfries, Scotland
 Latitude 55° 07' N
 Longitude 003° 21' W
 Date and Time (UTC): 21 December 1988 at 19.02:50 hrs
 All times in this report are UTC

SYNOPSIS

The accident was notified to the Air Accidents Investigation Branch at 19.40 hrs on the 21 December 1988 and the investigation commenced that day. The members of the AAIB team are listed at Appendix A.

The aircraft, Flight PA103 from London Heathrow to New York, had been in level cruising flight at flight level 310 (31,000 feet) for approximately seven minutes when the last secondary radar return was received just before 19.03 hrs. The radar then showed multiple primary returns fanning out downwind. Major portions of the wreckage of the aircraft fell on the town of Lockerbie with other large parts landing in the countryside to the east of the town. Lighter debris from the aircraft was strewn along two trails, the longest of which extended some 130 kilometres to the east coast of England. Within a few days items of wreckage were retrieved upon which forensic scientists found conclusive evidence of a detonating high explosive. The airport security and criminal aspects of the accident are the subject of a separate investigation and are not covered in this report which concentrates on the technical aspects of the disintegration of the aircraft.

The report concludes that the detonation of an improvised explosive device led directly to the destruction of the aircraft with the loss of all 259 persons on board and 11 of the residents of the town of Lockerbie. Five recommendations are made of which four concern flight recorders, including the funding of a study to devise methods of recording violent positive and negative pressure pulses associated with explosions. The final recommendation is that Airworthiness Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of the aircraft's structure and systems to explosive damage.

1. FACTUAL INFORMATION

1.1 History of the Flight

Boeing 747, N739PA, arrived at London Heathrow Airport from San Francisco and parked on stand Kilo 14, to the south-east of Terminal 3. Many of the passengers for this aircraft had arrived at Heathrow from Frankfurt, West Germany on a Boeing 727, which was positioned on stand Kilo 16, next to N739PA. These passengers were transferred with their baggage to N739PA which was to operate the scheduled Flight PA103 to New York Kennedy. Passengers from other flights also joined Flight PA103 at Heathrow. After a 6 hour turnround, Flight PA103 was pushed back from the stand at 18.04 hrs and was cleared to taxi on the inner taxiway to runway 27R. The only relevant Notam warned of work in progress on the outer taxiway. The departure was unremarkable.

Flight PA103 took-off at 18.25 hrs. As it was approaching the Burnham VOR it took up a radar heading of 350° and flew below the Bovingdon holding point at 6000 feet. It was then cleared to climb initially to flight level (FL) 120 and subsequently to FL 310. The aircraft levelled off at FL 310 north west of Pole Hill VOR at 18.56 hrs. Approximately 7 minutes later, Shanwick Oceanic Control transmitted the aircraft's oceanic clearance but this transmission was not acknowledged. The secondary radar return from Flight PA103 disappeared from the radar screen during this transmission. Multiple primary radar returns were then seen fanning out downwind for a considerable distance. Debris from the aircraft was strewn along two trails, one of which extended some 130 km to the east coast of England. The upper winds were between 250° and 260° and decreased in strength from 115 kt at FL 320 to 60 kt at FL 100 and 15 to 20 kt at the surface.

Two major portions of the wreckage of the aircraft fell on the town of Lockerbie; other large parts, including the flight deck and forward fuselage section, landed in the countryside to the east of the town. Residents of Lockerbie reported that, shortly after 19.00 hrs, there was a rumbling noise like thunder which rapidly increased to deafening proportions like the roar of a jet engine under power. The noise appeared to come from a meteor-like object which was trailing flame and came down in the north-eastern part of the town. A larger, dark, delta shaped object, resembling an aircraft wing, landed at about the same time in the Sherwood area of the town. The delta shaped object was not on fire while in the air, however, a very large fireball ensued which was of short duration and carried large amounts of debris into the air, the lighter particles being deposited several miles downwind. Other less well defined objects were seen to land in the area.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	16	243	11
Serious	-	-	2
Minor/None	-	-	3

1.3 Damage to aircraft

The aircraft was destroyed

1.4 Other damage

The wings impacted at the southern edge of Lockerbie, producing a crater whose volume, calculated from a photogrammetric survey, was approximately 560 cubic metres. The weight of material displaced by the wing impact was estimated to be well in excess of 1500 tonnes. The wing impact created a fireball, setting fire to neighbouring houses and carrying aloft debris which was then blown downwind for several miles. It was subsequently established that domestic properties had been so seriously damaged as a result of fire and/or impact that 21 had to be demolished and an even greater number of homes required substantial repairs. Major portions of the aircraft, including the engines, also landed on the town of Lockerbie and other large parts, including the flight deck and forward fuselage section, landed in the countryside to the east of the town. Lighter debris from the aircraft was strewn as far as the east coast of England over a distance of 130 kilometres.

1.5 Personnel information

1.5.1 Commander: Male, aged 55 years
Licence: USA Airline Transport Pilot's Licence

Aircraft ratings: Boeing 747, Boeing 707, Boeing 720, Lockheed L1011 and Douglas DC3
Medical Certificate: Class 1, valid to April 1989, with the limitation that the holder shall wear lenses that correct for distant vision and possess glasses that correct for near vision

Flying experience:

Total all types: 10,910 hours

Total on type: 4,107 hours

Total last 28 days 82 hours

Duty time: Commensurate with company requirements

Last base check: 11 November 1988

Last route check: 30 June 1988

Last emergencies check: 8 November 1988

1.5.2 Co-pilot: Male, aged 52 years

Licence: USA Airline Transport Pilot's Licence

Aircraft ratings: Boeing 747, Boeing 707, Boeing 727

Medical Certificate: Class 1, valid to April 1989, with the limitation that the holder shall possess correcting glasses for near vision

Flying experience:

Total all types: 11,855 hours

Total on type: 5,517 hours

Total last 28 days: 51 hours

Duty time: Commensurate with company requirements

Last base check: 30 November 1988

Last route check: Not required

Last emergencies check: 27 November 1988

1.5.3 Flight Engineer: Male, aged 46 years

Licence: USA Flight Engineer's Licence

Aircraft ratings: Turbojet

Medical certificate: Class 2, valid to June 1989, with the limitation that the holder shall wear correcting glasses for near vision

Flying experience:

Total all types: 8,068 hours

Total on type: 487 hours

Total last 28 days: 53 hours

Duty time: Commensurate with company requirements

Last base check: 30 October 1988

Last route check: Not required

Last emergencies check: 27 October 1988

1.5.4 Flight Attendants: There were 13 Flight Attendants on the aircraft, all of whom met company proficiency and medical requirements

1.6 Aircraft information

1.6.1 Leading particulars

Aircraft type: Boeing 747-121

Constructor's serial number: 19646

Engines: 4 Pratt and Whitney JT9D-7A turbofan

1.6.2 General description

The Boeing 747 aircraft, registration N739PA, was a conventionally designed long range transport aeroplane. A diagram showing the general arrangement is shown at Appendix B, Figure B-1 together with the principal dimensions of the aircraft.

The fuselage of the aircraft type was of approximately circular section over most of its length, with the forward fuselage having a diameter of 217 feet where the cross-section was constant. The pressurised section of the fuselage (which included the forward and aft cargo holds) had an overall length of 190 feet, extending from the nose to a point just forward of the tailplane. In normal cruising flight the service pressure differential was at the maximum value of 8.9 pounds per square inch. The fuselage was of conventional skin, stringer and frame construction, riveted throughout, generally using countersunk flush riveting for the skin panels. The fuselage frames were spaced at 20 inch intervals and given the same numbers as their stations, defined in terms of the distance in inches from the datum point close to the nose of the aircraft [Appendix B, Figure B-2]. The skin panels were joined using vertical butt joints and horizontal lap joints. The horizontal lap joints used three rows of rivets together with a cold bonded adhesive.

Accommodation within the aircraft was predominately on the main deck, which extended throughout the whole length of the pressurised compartment. A separate upper deck was incorporated in the forward part of the aircraft. This upper deck was reached by means of a spiral staircase from the main deck and incorporated the flight crew compartment together with additional passenger accommodation. The cross-section of the forward fuselage differed considerably from the near circular section of the remainder of the aircraft, incorporating an additional smaller radius arc above the upper deck section joined to the main circular arc of the lower cabin portion by elements of straight fuselage frames and flat skin.

In order to preserve the correct shape of the aircraft under pressurisation loading, the straight portions of the fuselage frames in the region of the upper deck floor and above it were required to be much stiffer than the frame portions lower down in the aircraft. These straight sections were therefore of very much more substantial construction than most of the curved sections of frames lower down and further back in the fuselage. There was considerable variation in the gauge of the fuselage skin at various locations in the forward fuselage of the aircraft.

The fuselage structure of N739PA differed from that of the majority of Boeing 747 aircraft in that it had been modified to carry special purpose freight containers on the main deck, in place of seats. This was known as the Civil Reserve Air Fleet (CRAF) modification and enabled the aircraft to be quickly converted for carriage of military freight containers on the main deck during times of national emergency. The effect of this modification on the structure of the fuselage was mainly to replace the existing main deck floor beams with beams of more substantial cross-section than those generally found in passenger carrying Boeing 747 aircraft. A large side loading door, generally known as the CRAF door, was also incorporated on the left side of the main deck aft of the wing.

Below the main deck, in common with other Boeing 747 aircraft, were a number of additional compartments, the largest of which were the forward and aft freight holds used for the storage of cargo and baggage in standard air-transportable containers. These containers were placed within the aircraft hold by means of a freight handling system and were carried on a system of rails approximately 2 feet above the outer skin at the bottom of the aircraft, there being no continuous floor, as such, below these baggage containers. The forward freight compartment had a length of approximately 40 feet and a depth of approximately 6 feet. The containers were loaded into the

forward hold through a large cargo door on the right side of the aircraft.

1.6.3 Internal fuselage cavities

Because of the conventional skin, frame and stringer type of construction, common to all large public transport aircraft, the fuselage was effectively divided into a series of 'bays'. Each bay, comprising two adjacent fuselage frames and the structure between them, provided, in effect, a series of interlinking cavities bounded by the frames, floor beams, fuselage skins and cabin floor panels etc. The principal cavities thus formed were:

- (i) A semi-circular cavity formed in between the fuselage frames in the lower lobe of the hull, i.e. from the crease beam (at cabin floor level) on one side down to the belly beneath the containers and up to the opposite crease beam, bounded by the fuselage skin on the outside and the containers/cargo liner on the inside [Appendix B, Figure B-3, detail A].
- (ii) A horizontal cavity between the main cabin floor beams, the cabin floor panels and the cargo bay liner. This extended the full width of the fuselage and linked the upper ends of the lower lobe cavity [Appendix B, Figure B-3, detail B].
- (iii) A narrow vertical cavity between the two containers [Appendix B, Figure B-3, detail C].
- (iv) A further narrow cavity around the outside of the two containers, between the container skins and the cargo bay liner, communicating with the lower lobe cavity [Appendix B, Figure B-3, detail D].
- (v) A continuation of the semi-circular cavity into the space behind the cabin wall liner [Appendix B, Figure B-3, detail E]. This space was restricted somewhat by the presence of the window assembly, but nevertheless provided a continuous cavity extending upwards to the level of the upper deck floor. Forward of station 740, this cavity was effectively terminated at its upper end by the presence of diaphragms which formed extensions of the upper deck floor panels; aft of station 740, the cavity communicated with the ceiling space and the cavity in the fuselage crown aft of the upper deck.

All of these cavities were repeated at each fuselage bay (formed between pairs of fuselage frames), and all of the cavities in a given bay were linked together, principally at the crease beam area [Appendix B, Figure B-3, region F]. Furthermore, each of the set of bay cavities was linked with the next by the longitudinal cavities formed between the cargo hold liner and the outer hull, just below the crease beam [Appendix B, Figure B-3, detail F]; i.e. this cavity formed a manifold linking together each of the bays within the cargo hold.

The main passenger cabin formed a large chamber which communicated directly with each of the sub floor bays, and also with the longitudinal manifold cavity, via the air conditioning and cabin/cargo bay de-pressurisation vent passages in the crease beam area. (It should be noted that a similar communication did not exist between the upper and lower cabins because there were no air conditioning/depressurisation passages to bypass the upper deck floor.)

1.6.4 Aircraft weight and centre of gravity

The aircraft was loaded within its permitted centre of gravity limits as follows:

Loading:	lb	kg	
Operating empty weight		366,228	166,120
Additional crew	130	59	
243 passengers (1)	40,324		18,291
Load in compartments:			

1	11,616	5,269	
2	20,039	9,090	
3	15,057	6,830	
4	17,196	7,800	
5	2,544	1,154	
Total in compartments (2)	66,452		30,143
Total traffic load	106,776		48,434
Zero fuel weight	472,156		214,554
Fuel (Take-off)	239,997		108,862
Actual take-off weight(4)	713,002		323,416
Maximum take-off weight	733,992		332,937

Note 1:

Calculated at standard weights and including cabin baggage.

Note 2:

Despatch information stated that the cargo did not include dangerous goods, perishable cargo, live animals or known security exceptions.

1.6.5 Maintenance details

N739PA first flew in 1970 and spent its whole service life in the hands of Pan American World Airways Incorporated. Its Certificate of Airworthiness was issued on 12 February 1970 and remained in force until the time of the accident, at which time the aircraft had completed a total of 72,464 hours flying and 16,497 flight cycles. Details of the last 4 maintenance checks carried out during the aircraft's life are shown below:

DATE	SERVICE	HOURS	CYCLES
27 Sept 88	C Check (Interior upgrade)	71,502	16,347
2 Nov 88	B Service Check	71,919	16,406
27 Nov 88	Base 1	72,210	16,454
13 Dec 88	Base 2	72,374	16,481

The CRAF modification programme was undertaken in September 1987. At the same time a series of modifications to the forward fuselage from the nose back to station 520 (Section 41) were carried out to enable the aircraft to continue in service without a continuing requirement for structural inspections in certain areas.

All Airworthiness Directives relating to the Boeing 747 fuselage structure between stations 500 and 1000 have been reviewed and their applicability to this aircraft checked. In addition, Service Bulletins relating to the structure in this area were also reviewed. The applicable Service Bulletins, some of which implement the Airworthiness Directives are listed below together with their subjects. The dates, total aircraft times and total aircraft cycles at which each relevant inspection was last carried out have been reviewed and their status on aircraft N739PA at the time of the accident has been established.

N739PA Service Bulletin compliance:

SB 53-2064 Front Spar Pressure Bulkhead Chord Reinforcement and Drag Splice Fitting Rework.

Modification accomplished on 6 July 1974.

Post-modification repetitive inspection IAW (in accordance with) AD 84-18-06 last accomplished on 19 November 1985 at 62,030 TAT hours (Total Aircraft Time) and 14,768 TAC (Total Aircraft Cycles).

SB 53-2088 Frame to Tension Tie Joint Modification - BS760 to 780.

Repetitive inspection IAW AD 84-19-01 last accomplished on 19 June 1985 at 60,153 hours TAT and 14,436 TAC.

SB 53-2200 Lower Cargo Doorway Lower Sill Truss and Latch Support Fitting Inspection Repair and Replacement.

Repetitive inspection IAW AD 79-17-02 R2 last accomplished 2 November 1988 at 71,919 hours TAT and 16,406 TAC.

SB 53-2234 Fuselage - Auxiliary Structure - Main Deck Floor - BS 480 Floor Beam Upper Chord Modification.

Repetitive inspection per SB 53A2263 IAW AD 86-23-06 last accomplished on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.

SB 53-2237 Fuselage - Main Frame - BS 540 thru 760 and 1820 thru 1900 Frame Inspection and Reinforcement.

Repetitive inspection IAW AD 86-18-01 last accomplished on 27 February 1987 at 67,088 hours TAT and 15,627 TAC.

SB 53-2267 Fuselage - Skin - Lower Body Longitudinal Skin Lap Joint and Adjacent Body Frame Inspection and Repair.

Terminating modification accomplished 100% under wing-to-body fairings and approximately 80% in forward and aft fuselage sections on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.

Repetitive inspection of unmodified lap joints IAW AD 86-09-07 R1 last accomplished on 18 August 1988 at 71,043 hours TAT and 16,273 TAC.

SB 53A2303 Fuselage - Nose Section - station 400 to 520 Stringer 6 Skin Lap Splice Inspection, Repair and Modification.

Repetitive inspection IAW AD 89-05-03 last accomplished on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.

This documentation, when viewed together with the detailed content of the above service bulletins, shows the aircraft to have been in compliance with the requirements laid down in each of those bulletins. Some maintenance items were outstanding at the time the aircraft was despatched on the last flight, however, none of these items relate to the structure of the aircraft and none had any relevance to the accident.

1.7 Meteorological Information

1.7.1 General weather conditions

An aftercast of the general weather conditions in the area of Lockerbie at about 19.00 hrs was obtained from the Meteorological Office, Bracknell. The synoptic situation included a warm sector covering northern England and most of Scotland with a cold front some 200 nautical miles to the west of the area moving eastwards at about 35 knots. The weather consisted of intermittent rain or showers. The cloud consisted of 4 to 6 oktas of stratocumulus based at 2,200 feet with 2 oktas of altocumulus between 15,000 and 18,000 feet. Visibility was over 15 kilometers and the freezing level was at 8,500 feet with a sub-zero layer between 4,000 and 5,200 feet.

1.7.2 Winds

There was a weakening jet stream of around 115 knots above Flight Level 310. From examination

of the wind profile (see below), there appeared to be insufficient shear both vertically and horizontally to produce any clear air turbulence but there may have been some light turbulence.

Flight Level	Wind
320	260°/115 knots
300	260°/ 90 knots
240	250°/ 80 knots
180	260°/ 60 knots
100	250°/ 60 knots
050	260°/ 40 knots
Surface	240°/ 15 to 20 gusting 25 to 30 knots

1.8 Aids to navigation

Not relevant.

1.9 Communications

The aircraft communicated normally on London Heathrow aerodrome, London control and Scottish control frequencies. Tape recordings and transcripts of all radio telephone (RTF) communications on these frequencies were available.

At 18.58 hrs the aircraft established two-way radio contact with Shanwick Oceanic Area Control on frequency 123.95 MHz. At 19.02:44 hrs the clearance delivery officer at Shanwick transmitted to the aircraft its oceanic route clearance. The aircraft did not acknowledge this message and made no subsequent transmission.

1.9.1 ATC recording replay

Scottish Air Traffic Control provided copy tapes with time injection for both Shanwick and Scottish ATC frequencies. The source of the time injection on the tapes was derived from the British Telecom "TIM" signal.

The tapes were replayed and the time signals corrected for errors at the time of the tape mounting.

1.9.2 Analysis of ATC tape recordings

From the cockpit voice recorder (CVR) tape it was known that Shanwick was transmitting Flight PA103's transatlantic clearance when the CVR stopped. By synchronising the Shanwick tape and the CVR it was possible to establish that a loud sound was heard on the CVR cockpit area microphone (CAM) channel at 19.02:50 hrs \pm 1 second.

As the Shanwick controller continued to transmit Flight PA103's clearance instructions through the initial destruction of the aircraft it would not have been possible for a distress call to be received from N739PA on the Shanwick frequency. The Scottish frequency tape recording was listened to from 19.02 hrs until 19.05 hrs for any unexplained sounds indicating an attempt at a distress call but none was heard.

A detailed examination and analysis of the ATC recording together with the flight recorder, radar, and seismic recordings is contained in Appendix C.

1.10 Aerodrome information

Not relevant

1.11 Flight recorders

The Digital Flight Data Recorder (DFDR) and the Cockpit Voice Recorder (CVR) were found close together at UK Ordnance Survey (OS) Grid Reference 146819, just to the east of Lockerbie, and recovered approximately 15 hours after the accident. Both recorders were taken directly to AAIB Farnborough for replay. Details of the examination and analysis of the flight recorders together with the radar, ATC and seismic recordings are contained in Appendix C.

1.11.1 Digital flight data recorder

The flight data recorder installation conformed to ARINC 573B standard with a Lockheed Model 209 DFDR receiving data from a Teledyne Controls Flight Data Acquisition Unit (FDAU). The system recorded 22 parameters and 27 discrete (event) parameters. The flight recorder control panel was located in the flight deck overhead panel. The FDAU was in the main equipment centre at the front end of the forward hold and the flight recorder was mounted in the aft equipment centre.

Decoding and reduction of the data from the accident flight showed that no abnormal behaviour of the data sensors had been recorded and that the recorder had simply stopped at 19.02:50 hrs \pm 1 second.

1.11.2 Cockpit voice recorder

The aircraft was equipped with a 30 minute duration 4 track Fairchild Model A100 CVR, and a Fairchild model A152 cockpit area microphone (CAM). The CVR control panel containing the CAM was located in the overhead panel on the flight deck and the recorder itself was mounted in the aft equipment centre.

The channel allocation was as follows:-

Channel 1	Flight Engineer's RTF.
Channel 2	Co-Pilot's RTF.
Channel 3	Pilot's RTF.
Channel 4	Cockpit Area Microphone.

The erase facility within the CVR was not functioning satisfactorily and low level communications from earlier recordings were audible on the RTF channels. The CAM channel was particularly noisy, probably due to the combination of the inherently noisy flight deck of the B747-100 in the climb and distortion from the incomplete erasure of the previous recordings. On two occasions the crew had difficulty understanding ATC, possibly indicating high flight deck noise levels. There was a low frequency sound present at irregular intervals on the CAM track but the source of this sound could not be identified and could have been of either acoustic or electrical origin.

The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual crew behaviour. The tape record ended, at 19.02:50 hrs \pm 1 second, with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording whilst the crew were copying their transatlantic clearance from Shanwick ATC.

1.12 Wreckage and impact information

1.12.1 General distribution of wreckage in the field

The complete wing primary structure, incorporating the centre section, impacted at the southern edge of Lockerbie. Major portions of the aircraft, including the engines, also landed in the town. Large portions of the aircraft fell in the countryside to the east of the town and lighter debris was strewn to the east as far as the North Sea. The wreckage was distributed in two trails which became known as the northern and southern trails respectively and these are shown in Appendix B, Figure B-4. A computer database of approximately 1200 significant items of wreckage was compiled and included a brief description of each item and the location where it was found

Appendix B, Figures B-5 to B-8 shows photographs of a model of the aircraft on which the fracture lines forming the boundaries of the separate items of structure have been marked. The model is colour coded to illustrate the way in which the wreckage was distributed between the town of Lockerbie and the northern and southern trails.

1.12.1.1 The crater

The aircraft wing impacted in the Sherwood Crescent area of the town leaving a crater approximately 47 metres (155 feet) long with a volume calculated to be 560 cubic metres.

The projected distance, measured parallel from one leading edge to the other wing tip, of the Boeing 747-100 was approximately 143 feet, whereas the span is known to be 196 feet. This suggests that impact took place with the wing structure yawed. Although the depth of the crater varied from one end to the other, its widest part was clearly towards the western end suggesting that the wing structure impacted whilst orientated with its root and centre section to the west.

The work carried out at the main crater was limited to assessing the general nature of its contents. The total absence of debris from the wing primary structure found remote from the crater confirmed the initial impression that the complete wing box structure had been present at the main impact.

The items of wreckage recovered from or near the crater are coloured grey on the model at Appendix B, Figures B-5 to B-8.

1.12.1.2 The Rosebank Crescent site

A 60 feet long section of fuselage between frame 1241 (the rear spar attachment) and frame 1960 (level with the rear edge of the CRAF cargo door) fell into a housing estate at Rosebank Crescent, just over 600 metres from the crater. This section of the fuselage was that situated immediately aft of the wing, and adjoined the wing and fuselage remains which produced the crater. It is colour coded yellow on the model at Appendix B, Figures B-5 to B-8. All fuselage skin structure above floor level was missing except for the following items:

- Section containing 3 windows between door 4L and CRAF door;
- The CRAF door itself (latched) apart from the top area containing the hinge;
- Window belt containing 8 windows aft of 4R door aperture
- Window belt containing 3 windows forward of 4R door aperture;
- Door 4R.

Other items found in the wreckage included both body landing gears, the right wing landing gear, the left and right landing gear support beams and the cargo door (frames 1800-1920) which was latched. A number of pallets, luggage containers and their contents were also recovered from this site.

1.12.1.3 Forward fuselage and flight deck section.

The complete fuselage forward of approximately station 480 (left side) to station 380 (right side) and incorporating the flight deck and nose landing gear was found as a single piece [Appendix B, Figure B-9] in a field approximately 4 km miles east of Lockerbie at OS Grid Reference 174808. It was evident from the nature of the impact damage and the ground marks that it had fallen almost flat on its left side but with a slight nose-down attitude and with no discernible horizontal velocity. The impact had caused almost complete crushing of the structure on the left side. The radome and right nose landing gear door had detached in the air and were recovered in the southern trail.

Examination of the torn edges of the fuselage skin did not indicate the presence of any pre-existing structural or material defects which could have accounted for the separation of this section of the fuselage. Equally so, there were no signs of explosive blast damage or sooting evident on any part of the structure or the interior fittings. It was noted however that a heavy, semi-elliptical scuff mark was present on the lower right side of the fuselage at approximately station 360. This was later matched to the intake profile of the No 3 engine.

The status of the controls and switches on the flight deck was consistent with normal operation in cruising flight. There were no indications that the crew had attempted to react to rapid decompression or loss of control or that any emergency preparations had been actioned prior to the catastrophic disintegration.

1.12.1.4 Northern trail

The northern trail was seen to be narrow and clearly defined, to emanate from a point very close to the main impact crater and to be orientated in a direction which agreed closely with the mean wind aftercast for the height band from sea level to 20,000 ft. Also at the western end of the northern trail were the lower rear fuselage at Rosebank Crescent, and the group of Nos. 1, 2 and 4 engines which fell in Lockerbie.

The trail contained items of structure distributed throughout its length, from the area slightly east of the crater, to a point approximately 16 km east, beyond which only items of low weight / high drag such as insulation, interior trim, paper etc, were found. For all practical purposes this trail ended at a range of 25 km.

The northern trail contained mainly wreckage from the rear fuselage, fin and the inner regions of both tailplanes together with structure and skin from the upper half of the fuselage forward to approximately the wing mid-chord position. A number of items from the wing were also found in the northern trail, including all 3 starboard Kreuger flaps, most of the remains of the port Kreuger flaps together with sections of their leading edge attachment structures, one portion of outboard aileron approximately 10 feet long, the aft ends of the flap-track fairings (one with a slide raft wrapped around it), and fragments of glass reinforced plastic honeycombe structure believed to be from the flap system, i.e. fore-flaps, aft-flaps, mid-flaps or adjacent fairings. In addition, a number of pieces of the engine cowlings and both HF antennae (situated projecting aft from the wing-tips) were found in this trail.

All items recovered from the northern trail, with the exception of the wing, engines, and lower rear fuselage in Rosebank Crescent, are coloured red on the model of the aircraft in Appendix B, Figures B-5 to B-8.

1.12.1.5 Southern trail

The southern trail was easily defined, except within 12 km of Lockerbie where it tended to merge with the northern trail. Further east, it extended across southern Scotland and northern England, essentially in a straight band as far as the North Sea. Most of the significant items of wreckage were found in this trail within a range of 30 km from the main impact crater. Items recovered from the southern trail are coloured green on the model of the aircraft at Appendix B, Figures B-5 to B-8.

The trail contained numerous large items from the forward fuselage. The flight deck and nose of the aircraft fell in the curved part of this trail close to Lockerbie. Fragments of the whole of the left tailplane and the outboard portion of the right tailplane were distributed almost entirely throughout the southern trail. Between 21 and 27 km east of the main impact point (either side of Langholm) substantial sections of tailplane skin were found, some bearing distinctive signs of contact with debris moving outwards and backwards relative to the fuselage. Also found in this area were numerous isolated sections of fuselage frame, clearly originating from the crown region above the forward upper deck.

1.12.1.6 Datum line

All grid references relating to items bearing actual explosive evidence, together with those attached to heavily distorted items found to originate immediately adjacent to them on the structure, were plotted on an Ordnance Survey (OS) chart. These references, 11 in total, were all found to be distributed evenly about a mean line orientated 079° (Grid) within the southern trail and were spread over a distance of 12 km. The distance of each reference from the line was measured in a direction parallel to the aircraft's track and all were found to be within 500 metres of the line, with 50% of them being within 250 metres of the line. This line is referred to as the datum line and is shown in Appendix B, Figure B-4.

1.12.1.7 Distribution of wreckage within the southern trail

North of the datum line and parallel to it were drawn a series of lines at distances of 250, 300, 600 and 900 metres respectively from the line, again measured in a direction parallel to the aircraft's track. The positions on the aircraft structure of specific items of wreckage, for which grid references were known with a high degree of confidence, within the bands formed between these lines, are shown in Appendix B, Figures B-10 to 13. In addition, a separate assessment of the grid references of tailplane and elevator wreckage established that these items were distributed evenly about the 600 metre line.

1.12.1.8 Area between trails

Immediately east of the crater, the southern trail converged with the northern trail such that, to an easterly distance of approximately 5 km, considerable wreckage existed which could have formed part of either trail. Further east, between 6 and 11 km from the crater, a small number of sections and fragments of the fin had fallen outside the southern boundary of the northern trail. Beyond this a large area existed between the trails in which there was no wreckage.

1.12.2 Examination of wreckage at CAD Longtown

The debris from all areas was recovered by the Royal Air Force to the Army Central Ammunition Depot Longtown, about 20 miles from Lockerbie. Approximately 90% of the hull wreckage was successfully recovered, identified, and laid out on the floor in a two-dimensional reconstruction [Appendix B, Figure B-14]. Baggage container material was incorporated into a full three-dimensional reconstruction. Items of wreckage added to the reconstructions was given a reference number and recorded on a computer database together with a brief description of the item and the location where it was found.

1.12.2.1 Fuselage

The reconstruction revealed the presence of damage consistent with an explosion on the lower fuselage left side in the forward cargo bay area. A small region of structure bounded approximately by frames 700 & 720 and stringers 38L & 40L, had clearly been shattered and blasted through by material exhausting directly from an explosion centred immediately inboard of this location. The material from this area, hereafter referred to as the 'shatter zone', was mostly reduced to very small fragments, only a few of which were recovered, including a strip of two skins [Appendix B, Figure B-15] forming part of the lap joint at the stringer 39L position.

Surrounding the shatter zone were a series of much larger panels of torn fuselage skin which formed a 'star-burst' fracture pattern around the shatter zone. Where these panels formed the boundary of the shatter zone, the metal in the immediate locality was ragged, heavily distorted, and the inner surfaces were pitted and sooted - rather as if a very large shotgun had been fired at the inner surface of the fuselage at close range. In contrast, the star-burst fractures, outside the boundary of the shatter zone, displayed evidence of more typical overload tearing, though some tears appeared to be rapid and, in the area below the missing panels, were multi-branched. These surrounding skin panels were moderately sooted in the regions adjacent to the shatter zone, but otherwise were lightly sooted or free of soot altogether. (Forensic analysis of the soot deposits on frame and skin material from this area confirmed the presence of explosive residues.) All of these skin panels had pulled away from the supporting structure and had been bent and torn in a manner which indicated that, as well as fracturing in the star burst pattern, they had also petalled outwards producing characteristic, tight curling of the sheet material.

Sections of frames 700 and 720 from the area of the explosion were also recovered and identified. Attached to frame 720 were the remnants of a section of the aluminium baggage container (side) guide rail, which was heavily distorted and displayed deep pitting together with very heavy sooting, indicating that it had been very close to the explosive charge. The pattern of distortion and damage on the frames and guide rail segment matched the overall pattern of damage observed on the skins.

The remainder of the structure forming the cargo deck and lower hull was, generally, more randomly distorted and did not display the clear indications of explosive processes which were evident on the skin panels and frames nearer the focus of the explosion. Nevertheless, the overall pattern of damage was consistent with the propagation of explosive pressure fronts away from the focal area inboard of the shatter zone. This was particularly evident in the fracture and bending characteristics of several of the fuselage frames ahead of, and behind station 700.

The whole of the two-dimensional fuselage reconstruction was examined for general evidence of the mode of disintegration and for signs of localised damage, including overpressure damage and

pre-existing damage such as corrosion or fatigue. There was some evidence of corrosion and dis-bonding at the cold-bond lap joints in the fuselage. However, the corrosion was relatively light and would not have compromised significantly the static strength of the airframe. Certainly, there was no evidence to suggest that corrosion had affected the mode of disintegration, either in the area of the explosion or at areas more remote. Similarly, there were no indications of fatigue damage except for one very small region of fatigue, involving a single crack less than 3 inches long, which was remote from the bomb location. This crack was not in a critical area and had not coincided with a fracture path.

No evidence of overpressure fracture or distortion was found at the rear pressure bulkhead. Some suggestion of 'quilting' or 'pillowing' of skin panels between stringers and frames, indicative of localised overpressure, was evident on the skin panels attached to the larger segments of lower fuselage wreckage aft of the blast area. In addition, the mode of failure of the butt joint at station 520 suggested that there had been a rapid overpressure load in this area, causing the fastener heads to 'pop' in the region of stringers 13L to 16L, rather than producing shear in the fasteners. Further evidence of localised overpressure damage remote from the source of the explosion was found during the full three-dimensional reconstruction, detailed later in paragraph 1.12.3.2.

An attempt was made to analyse the fractures, to determine the direction and sequence of failure as the fractures propagated away from the region of the explosion. It was found that the directions of most of the fractures close to the explosion could be determined from an analysis of the fracture surfaces and other features, such as rivet and rivet hole distortions. However, it was apparent that beyond the boundary of the petalled region, the disintegration process had involved multiple fractures taking place simultaneously - extremely complex parallel processes which made the sequencing of events not amenable to conventional analysis.

1.12.2.2 Wing structure and adjacent fuselage area

On completion of the initial layout at Longtown it became evident that, in the area from station 1000 to approximately station 1240 the only identifiable fuselage structure consisted of elements of fuselage skin, stringers and frames from above the cabin window belts. The wreckage from in and around the crater was therefore sifted to establish more accurately what sections of the aircraft had produced the crater. All of the material was highly fragmented, but it was confirmed that the material comprised mostly wing structure, with a few fragments of fuselage sidewall and passenger seats. The badly burnt state of these fragments made it clear that they were recovered from the area of the main impact crater, the only scene of significant ground fire. Amongst these items a number of cabin window forgings were recovered with sections of thick horizontal panelling attached having a length equivalent to the normal window spacing/frame pitch. This arrangement, with skins of this thickness, is unique to the area from station 1100 to 1260. It is therefore reasonable to assume that these fragments formed parts of the missing cabin sides from station 1000 to station 1260, which must have remained attached to the wing centre section at the time of its impact. Because of the high degree of fragmentation and the relative insignificance of the wing in terms of the overall explosive damage pattern, a reconstruction of the wing material was not undertaken. The sections of the aircraft which went into the crater are colour coded grey in Appendix B, Figures B-5 to B-8.

1.12.2.3 Fin and aft section of fuselage

Examination of the structure of the fin revealed evidence of in-flight damage to the leading edge

caused by the impact of structure or cabin contents. This damage was not severe or extensive and the general break-up of the fin did not suggest either a single readily defined loading direction, or break-up due to the effects of leading edge impact. A few items of fin debris were found between the northern and southern trails.

A number of sections of fuselage frame found in the northern trail exhibited evidence of plastic deformation of skin attachment cleats and tensile overload failure of the attachment rivets. This damage was consistent with that which would occur if the skin had been locally subjected to a high loading in a direction normal to its plane. Although this was suggestive of an internal overpressure condition, the rear fuselage revealed no other evidence to support this possibility. Examination of areas of the forward fuselage known to have been subjected to high blast overpressures revealed no comparable evidence of plastic deformation in the skin attachment cleats or rivets, most skin attachment failures appearing to have been rapid.

Calculations made on the effects of internal pressure generated by an open ended fuselage descending at the highest speed likely to have been experienced revealed that this could not generate an internal pressure approaching that necessary to cause failure in an intact cabin structure.

1.12.2.4 Baggage containers

During the wreckage recovery operation it became apparent that some items, identified as parts of baggage containers, exhibited damage consistent with being close to a detonating high explosive. It was therefore decided to segregate identifiable container parts and reconstruct any that showed evidence of explosive damage. It was evident, from the main wreckage layout, that the explosion had occurred in the forward cargo hold and, although all baggage container wreckage was examined, only items from this area which showed the relevant characteristics were considered for the reconstruction. Discrimination between forward and rear cargo hold containers was relatively straightforward as the rear cargo hold wreckage was almost entirely confined to Lockerbie, whilst that from the forward hold was scattered along the southern wreckage trail.

All immediately identifiable parts of the forward cargo containers were segregated into areas designated by their serial numbers and items not identified at that stage were collected into piles of similar parts for later assessment. As a result of this, two adjacent containers, one of metal construction the other fibreglass, were identified as exhibiting damage likely to have been caused by the explosion. Those parts which could be positively identified as being from these two containers were assembled onto one of three simple wooden frameworks, one each for the floor and superstructure of the metal container and one for the superstructure of the fibreglass container. From this it was positively determined that the explosion had occurred within the metal container (serial number AVE 4041 PA), the direct effects of this being evident also on the forward face of the adjacent fibreglass container (serial number AVN 7511 PA) and on the local airframe on the left side of the aircraft in the region of station 700. It was therefore confirmed that this metal container had been loaded in position 14L in agreement with the aircraft loading records. While this work was in progress a buckled section of the metal container skin was found by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device (IED).

The reconstruction of these containers and their relationship to the aircraft structure is described in detail in Appendix F. Examination of all other components of the remaining containers revealed only damage consistent with ejection into the high speed slipstream and/or ground impact, and that

only one device had detonated within the containers on board the aircraft.

1.12.3 Fuselage three-dimensional reconstruction

1.12.3.1 The reconstruction

The two-dimensional reconstruction successfully established that there had been an explosion in the forward hold; its location was established and the general damage characteristics in the vicinity of the explosion were determined. However, the mechanisms by which the failure process developed from local damage in the immediate vicinity of the explosion to the complete structural break-up and separation of the whole forward section of the fuselage, could not be adequately investigated without recourse to a more elaborate reconstruction.

To facilitate this additional work, wreckage forming a 65 foot section of the fuselage (approximately 30 feet each side of the explosion) was transported to AAIB Farnborough, where it was attached to a specially designed framework to form a fully three-dimensional reconstruction [Appendix B, Figures B-16 and B-17] of the complete fuselage between stations 360 & 1000 (from the separated nose section back to the wing cut out). The support framework was designed to provide full and free access to all parts of the structure, both internally and externally. Because of height constraints, the reconstruction was carried out in two parts, with the structure divided along a horizontal line at approximately the upper cabin floor level. The previously reconstructed containers were also transported to AAIB Farnborough to allow correlation of evidence with, and partial incorporation into, the fuselage reconstruction.

Structure and skin panels were attached to the supporting framework by their last point of attachment, to provide a better appreciation of the modes and direction of curling, distortion, and ultimate separation. Thus, the panels of skin which had petalled back from the shatter zone were attached at their outer edges, so as to identify the bending modes of the panels, the extent of the petalled region, and also the size of the resulting aperture in the hull. In areas more remote from the explosion, the fracture and tear directions were used together with distortion and curling directions to determine the mode of separation, and thus the most appropriate point of attachment to the reconstruction. Cabin floor beam segments were supported on a steel mesh grid and a plot of the beam fractures is shown at Appendix B, Figure B-18.

The cargo container base elements were separated from the rest of the container reconstruction and transferred to the main wreckage reconstruction, where the re-assembled container base was positioned precisely onto the cargo deck. To assist in the correlation of the initial shatter zone and petalled-out regions with the position of the explosive device, the boundaries of the skin panel fractures were marked on a transparent plastic panel which was then attached to the reconstruction to provide a transparent pseudo-skin showing the positions of the skin tear lines. This provided a clear visual indication of the relationship between the skin panel fractures and the explosive damage to the container base, thus providing a more accurate indication of the location of the explosive device.

1.12.3.2 Summary of explosive features evident

The three-dimensional reconstruction provided additional information about the region of tearing and petalling around the shatter zone. It also identified a number of other regions of structural damage, remote from the explosion, which were clearly associated with severe and rapidly applied pressure loads acting normal to the skin's internal surface. These were sufficiently sharp-edged to pre-empt the resolution of pressure induced loads into membrane tension stresses in the skin:

instead, the effect was as though these areas of skin had been struck a severe 'pressure blow' from within the hull.

The two types of damage, i.e. the direct blast/tearing/petalling damage and the quite separate areas of 'pressure blow' damage at remote sites were evidently caused by separate mechanisms, though it was equally clear that each was caused by explosive processes, rather than more general disintegration.

The region of petalling was bounded (approximately) by frames 680 and 740, and extended from just below the window belt down nearly to the keel of the aircraft [Appendix B, Figure B-19, region A]. The resulting aperture measured approximately 17 feet by 5 feet. Three major fractures had propagated beyond the boundary of the petalled zone, clearly driven by a combination of hull pressurisation loading and the relatively long term (secondary) pressure pulse from the explosion. These fractures ran as follows:

- (i) rearwards and downward in a stepped fashion, joining the stringer 38L lap joint at around station 840, running aft along stringer 38L to around station 920, then stepping down to stringer 39L and running aft to terminate at the wing box cut-out [Appendix B, Figure B-19, fracture 1].
- (ii) downwards and forward to join the stringer 44L lap joint, then running forward along stringer 44L as far as station 480 [Appendix B, Figure B-19, fracture 2].
- (iii) downwards and rearward, joining the butt line at station 740 to run under the fuselage and up the right side to a position approximately 18 inches above the cabin floor level [Appendix B, Figures B-19 and B-20, fracture 3].

The propagation of tears upwards from the shatter zone appeared to have taken the form of a series of parallel fractures running upwards together before turning towards each other and closing, forming large flaps of skin which appear to have separated relatively cleanly.

Regions of skin separation remote from the site of the explosion were evident in a number of areas. These principally were:

- (i) A large section of upper fuselage skin extending from station 500 back to station 760, and from around stringers 15/19L up as far as stringer 5L [Appendix B, Figures B-19 and B-20, region B], and probably extending further up over the crown. This panel had separated initially at its lower forward edge as a result of a pressure blow type of impulse loading, which had popped the heads from the rivets at the butt joint on frame 500 and lifted the skin flap out into the airflow. The remainder of the panel had then torn away rearwards in the airflow. A region of 'quilting' or 'pillowing', i.e. spherical bulging of skin panels between frames and stringers, was evident on these panels in the region between station 560 and 680, just below the level of the upper deck floor, indicative of high internal pressurisation loading [Appendix B, Figure B-19, region C].
- (ii) A smaller section of skin between stations 500 and 580, bounded by stringers 27L and 34L [Appendix B, Figure B-19, region D], had also been 'blown' outwards at its forward edge and torn off the structure rearwards. A characteristic curling of the panel was evident, consistent with rapid, energetic separation from the structure.
- (iii) A section of thick belly skin extending from station 560, stringers 40R to 44R, and tapering back to a point at stringer 45R/station 720 [Appendix B, Figure B-19 and B-20, region E], had separated from the structure as a result of a very heavy 'pressure blow' load at its forward end which had popped the heads off a large number of substantial skin fasteners. The panel had then torn away rearwards from the structure, curling up tightly onto itself as it did so - indicating that considerable excess energy was involved in the separation process (over and above that needed

simply to separate the skin material from its supporting structure).

(iv) A panel of skin on the right side of the aircraft, roughly opposite the explosion, had been torn off the frames, beginning at the top edge of the panel situated just below the window belt and tearing downwards towards the belly [Appendix B, Figure B-20, region F]. This panel was curled downwards in a manner which suggested significant excess energy.

Appendix B, Figure B-21 shows a plot of the fractures noted in the fuselage skins between stations 360 and 1000.

The cabin floor structure was badly disrupted, particularly in the general area above the explosion, where the floor beams had suffered localised upward loading sufficient to fracture them, and the floor panels were missing. Elsewhere, floor beam damage was mainly limited to fractures at the outer ends of the beams and at the centreline, leaving sections of separated floor structure comprising a number of half beams joined together by the Nomex honeycomb floor panels.

1.12.3.3 General damage features not directly associated with explosive forces.

A number of features appeared to be a part of the general structural break-up which followed on from the explosive damage, rather than being a part of the explosive damage process itself. This general break-up was complex and, to a certain extent, random. However, analysis of the fractures, surface scores, paint smears and other features enabled a number of discreet elements of the break-up process to be identified. These elements are summarised below.

(i) Buckling of the window belts on both sides of the aircraft was evident between stations 660 and 800. That on the left side appeared to be the result of in-plane bending in a nose up sense, followed by fracture. The belt on the right side had a large radius curve suggesting lateral deflection of the fuselage possibly accompanied by some longitudinal compression. This terminated in a peeling failure of the riveted joint at station 800.

(ii) On the left side three fractures, apparently resulting from in-plane bending/buckling distortion, had traversed the window belt [Appendix B, Figure B-21, detail G]. Of these, the forward two had broken through the window apertures and the aft fracture had exploited a rivet line at the region of reinforcement just forward of the L2 door aperture. On the right side, the window belt had peeled rearwards, after buckling had occurred, separating from the rest of the fuselage, following rivet failure, at the forward edge of the R2 door aperture.

(iii) All crown skins forward of frame 840 were badly distorted and a number of pieces were missing. It was clearly evident that the skin sections from this region had struck the empennage and/or other structure following separation.

(iv) The fuselage left side lower lobe from station 740 back to the wing box cut-out, and from the window level down to the cargo deck floor (the fracture line along stringer 38L), had peeled outwards, upwards and rearwards - separating from the rest of the fuselage at the window belt. The whole of this separated section had then continued to slide upwards and rearwards, over the fuselage, before being carried back in the slipstream and colliding with the outer leading edge of the right horizontal stabiliser, completely disrupting the outer half. A fragment of horizontal stabiliser spar cap was found embedded in the fuselage structure adjacent to the two vent valves, just below, and forward of, the L2 door [Appendix B, Figure B-22].

(v) A large, clear, imprint of semi-elliptical form was apparent on the lower right side at station 360 which had evidently been caused by the separating forward fuselage section striking the No 3 engine as it swung rearwards and to the right (confirmed by No 3 engine fan cowl damage).

1.12.3.4 Tailplane three-dimensional reconstruction

The tailplane structural design took the form of a forward and an aft torque box. The forward box was constructed from light gauge aluminium alloy sheet skins, supported by closely pitched, light gauge nose ribs but without lateral stringers. The aft torque box incorporated heavy gauge skin/stringer panels with more widely spaced ribs. The front spar web was of light gauge material. Leading edge impacts inflicted by debris would therefore have had the capacity to reduce the tailplane's structural integrity by passing through the light gauge skins and spar web into the interior of the aft torque box, damaging the shear connection between top and bottom skins in the process and thereby both removing the bending strength of the box and opening up the weakened structure to the direct effects of the airflow.

Examination of the rebuilt tailplane structure at AAIB Farnborough left little doubt that it had been destroyed by debris striking its leading edges. In addition, the presence on the skins of smear marks indicated that some unidentified soft debris had contacted those surfaces whilst moving with both longitudinal and lateral velocity components relative to the aircraft.

The reconstructed left tailplane [Appendix B, Figure B-23] showed evidence that disruption of the inboard leading edge, followed respectively by the forward torque box, front spar web and main torque box, occurred as a result of frontal impact by the base of a baggage container. Further outboard, a compact object appeared to have struck the underside of the leading edge and penetrated to the aft torque box. In both cases, the loss of the shear web of the front spar appeared to have permitted local bending failure of the remaining main torque box structure in a tip downwards sense, consistent with the normal load direction. For both events to have occurred it would be reasonable to assume that the outboard damage preceded that occurring inboard.

The right tailplane exhibited massive leading edge impact damage on the outboard portion which also appeared to have progressed to disruption of the aft torsion box. A fragment of right tailplane spar cap was found embedded in the fuselage structure adjacent to the two vent valves, just below, and forward of, the L2 door and it is clear that this area of forward left fuselage had travelled over the top of the aircraft and contributed to the destruction of the outboard right tailplane.

1.12.4 Examination of engines

All four engines had struck the ground in Lockerbie with considerable velocity and therefore sustained major damage, in particular to most of the fan blades. The No 3 engine had fallen 1,100 metres north of the other three engines, striking the ground on its rear face, penetrating a road surface and coming to rest without any further change of orientation i.e. with the front face remaining uppermost. The intake area contained a number of loose items originating from within the cabin or baggage hold. It was not possible initially to determine whether any of the general damage to any of the engine fans or the ingestion noted in No 3 engine intake occurred whilst the relevant engines were delivering power or at a later stage.

Numbers 1, 2 and 3 engines were taken to British Airways Engine Overhaul Limited for detailed examination under AAIB supervision in conjunction with a specialist from the Pratt and Whitney Engine Company. During this examination the following points were noted:

(i) No 2 engine (situated closest to the site of the explosion) had evidence of blade "shingling" in the area of the shrouds consistent with the results of major airflow disturbance whilst delivering power. (This effect is produced when random bending and torsional deflection occurs, permitting the mid-span shrouds to disengage and repeatedly strike the adjacent aerofoil surfaces of the blades). The interior of the air intake contained paint smears and other evidence suggesting the

passage of items of debris. One such item of significance was a clear indentation produced by a length of cable of diameter and strand size similar to that typically attached to the closure curtains on the baggage containers.

(ii) No 3 engine, identified on site as containing ingested debris from within the aircraft, nonetheless had no evidence of the type of shingling seen on the blades of No 2 engine. Such evidence is usually unmistakable and its absence is a clear indication that No 3 engine did not suffer a major intake airflow disturbance whilst delivering significant power. The intake structure was found to have been crushed longitudinally by an impact on the front face although, as stated earlier, it had struck the ground on its rear face whilst falling vertically.

(iii) All 3 engines had evidence of blade tip rubs on the fan cases having a combination of circumference and depth greater than hitherto seen on any investigation witnessed on Boeing 747 aircraft by the Pratt and Whitney specialists. Subsequent examination of No 4 engine confirmed that it had a similar deep, large circumference tip rub. These tip-rubs on the four engines were centred at slightly different clock positions around their respective fan cases.

The Pratt and Whitney specialists supplied information which was used to interpret the evidence found on the blades and fan cases including details of engine dynamic behaviour necessary to produce the tip rub evidence. This indicated that the depth and circumference of tip rubs noted would have required a marked nose down change of aircraft pitch attitude combined with a roll rate to the left.

Pratt and Whitney also advised that:

(i) Airflow disruption such as that presumed to have caused the shingling observed on No 2 engine fan blades was almost invariably the result of damage to the fan blade aerofoils, resulting from ingestion or blade failure.

(ii) Tip rubs of a depth and circumference noted on all four engines could be expected to reduce the fan rotational energy on each to a negligible value within approximately 5 seconds.

(iii) Airflow disruption sufficient to cause the extent of shingling noted on the fan blades of No 2 engine would also reduce the rotational fan energy to a negligible value within approximately 5 seconds.

1.13 Medical and pathological information

The results of the post mortem examination of the victims indicated that the majority had experienced severe multiple injuries at different stages, consistent with the in-flight disintegration of the aircraft and ground impact. There was no pathological indication of an in-flight fire and no evidence that any of the victims had been injured by shrapnel from the explosion. There was also no evidence which unequivocally indicated that passengers or cabin crew had been killed or injured by the effects of a blast. Although it is probable that those passengers seated in the immediate vicinity of the explosion would have suffered some injury as a result of blast, this would have been of a secondary or tertiary nature.

Of the casualties from the aircraft, the majority were found in areas which indicated that they had been thrown from the fuselage during the disintegration. Although the pattern of distribution of bodies on the ground was not clear cut there was some correlation with seat allocation which suggested that the forward part of the aircraft had broken away from the rear early in the disintegration process. The bodies of 10 passengers were not recovered and of these, 8 had been allocated seats in rows 23 to 28 positioned over the wing at the front of the economy section. The fragmented remains of 13 passengers who had been allocated seats around the eight missing persons were found in or near the crater formed by the wing. Whilst there is no unequivocal proof

that the missing people suffered the same fate, it would seem from the pattern that the missing passengers remained attached to the wing structure until impact.

1.14 Fire

Of the several large pieces of aircraft wreckage which fell in the town of Lockerbie, one was seen to have the appearance of a ball of fire with a trail of flame. Its final path indicated that this was the No 3 engine, which embedded itself in a road in the north-east part of the town. A small post impact fire posed no hazard to adjacent property and was later extinguished with water from a hosereel. The three remaining engines landed in the Netherplace area of the town. One severed a water main and the other two, although initially on fire, were no risk to persons or property and the fires were soon extinguished.

A large, dark, delta shaped object was seen to fall at about the same time in the Sherwood area of the town. It was not on fire while in the air, however, a fireball several hundred feet across followed the impact. It was of relatively short duration and large amounts of debris were thrown into the air, the lighter particles being carried several miles downwind, while larger pieces of burning debris caused further fires, including a major one at the Townfoot Garage, up to 350 metres from the source. It was determined that the major part of both wings, which included the aircraft fuel tanks, had formed the crater. A gas main had also been ruptured during the impact.

At 19.04 hrs the Dumfries Fire Brigade Control received a call from a member of the public which indicated that there had been a "huge boiler explosion" at Westacres, Lockerbie, however, subsequent calls soon made it clear that it was an aircraft which had crashed. At 19.07 hrs the first appliances were mobile and at 19.10 hrs one was in attendance in the Rosebank area. Multiple fires were identified and it soon became apparent that a major disaster had occurred in the town and the Fire Brigade Major Incident Plan was implemented. During the initial phase 15 pumping appliances from various brigades were deployed but this number was ultimately increased to 20.

At 22.09 hrs the Firemaster made an assessment of the situation. He reported that there was a series of fires over an area of the town centre extending 1½ by ½ mile. The main concentration of the fire was in the southwest of the town around Sherwood Park and Sherwood Crescent. Appliances were in attendance at other fires in the town, particularly in Park Place and Rosebank Crescent. Water and electricity supplies were interrupted and water had to be brought into the town.

By 02.22 hrs on 22 December, all main seats of fire had been extinguished and the firemen were involved in turning over and damping down. At 04.42 hrs small fires were still occurring but had been confined to the Sherwood Crescent area.

1.15 Survival aspects

1.15.1 Survivability

The accident was not survivable.

1.15.2 Emergency services

A chronology of initial responses by the emergency services is listed below:-

Time	Event
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19.03 hrs Radio message from Police patrol in Lockerbie to Dumfries and Galloway Constabulary reporting an aircraft crash at Lockerbie.
19.04 hrs Emergency call to Dumfries and Galloway Fire Brigade.
19.37 hrs First ambulances leave for Dumfries and Galloway Royal Infirmary with injured town residents. (2- serious; 3- minor)
19.40 hrs Sherwood Park and Sherwood Crescent residents evacuated to Lockerbie Town Hall.
20.25 hrs Nose section of N739PA discovered at Tundergarth (approximately 4 km east of Lockerbie).

During the next few days a major emergency operation was mounted using the guidelines of the Dumfries and Galloway Regional Peacetime Emergency Plan. The Dumfries and Galloway Constabulary was reinforced by contingents from Strathclyde and Lothian & Borders Constabularies. Resources from HM Forces were made available and this support was subsequently authorised by the Ministry of Defence as Military Aid to the Civil Power. It included the provision of military personnel and a number of helicopters used mainly in the search for and recovery of aircraft wreckage. It was apparent at an early stage that there were no survivors from the aircraft and the search and recovery of bodies was mainly a Police task with military assistance.

Many other agencies were involved in the provision of welfare and support services for the residents of Lockerbie, relatives of the aircraft's occupants and personnel involved in the emergency operation.

1.16 Tests and research

An explosive detonation within a fuselage, in reasonably close proximity to the skin, will produce a high intensity spherically propagating shock wave which will expand outwards from the centre of detonation. On reaching the inner surface of the fuselage skin, energy will partially be absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of the remaining energy will be transmitted, as a shock wave, through the skin and into the atmosphere but a significant amount of energy will be returned as a reflected shock wave, which will travel back into the fuselage interior where it will interact with the incident shock to produce Mach stem shocks - re-combination shock waves which can have pressures and velocities of propagation greater than the incident shock.

The Mach stem phenomenon is significant because it gives rise (for relatively small charge sizes) to a geometric limitation on the area of skin material which the incident shock wave can shatter, irrespective of charge size, thus providing a means of calculating the standoff distance of the explosive charge from the fuselage skin. Calculations suggest that a charge standoff distance of approximately 25 inches would result in a shattered region approximately 18 to 20 inches in diameter, comparable to the size of the shattered region evident in the wreckage. This aspect is covered in greater detail in [Appendix G].

1.17 Additional information

1.17.1 Recorded radar information

Recorded radar information on the aircraft was available from 4 radar sites. Initial analysis consisted of viewing the recorded information as it was shown to the controller on the radar screen from which it was clear that the flight had progressed in a normal manner until secondary

surveillance radar (SSR) was lost.

The detailed analysis of the radar information concentrated on the break-up of the aircraft. The Royal Signals and Radar Establishment (RSRE) corrected the radar returns for fixed errors and converted the SSR returns to latitude and longitude so that an accurate time and position for the aircraft could be determined. The last secondary return from the aircraft was recorded at 19.02:46.9 hrs, identifying N739PA at Flight Level 310, and at the next radar return there is no SSR data, only 4 primary returns. It was concluded that the aircraft was, by this time, no longer a single return and, considering the approximately 1 nautical mile spread of returns across track, that items had been ejected at high speed probably to both right and left of the aircraft.

Each rotation of the radar head thereafter showed the number of returns increasing, with those first identified across track having slowed down very quickly and followed a track along the prevailing wind line. The radar evidence then indicated that a further break-up of the aircraft had occurred and formed a parallel wreckage trail to the north of the first. From the absence of any returns travelling along track it was concluded that the main wreckage was travelling almost vertically downwards for much of the time.

A detailed analysis of the recorded radar information, together with the radar, ATC and seismic recordings is contained in Appendix C.

1.17.2 Seismic data

The British Geological Survey has a number of seismic monitoring stations in Southern Scotland. Stations close to Lockerbie recorded a seismic event measuring 1.6 on the Richter scale and, with appropriate corrections for the times of the waves to reach the sensors, it was established that this occurred at 19.03:36.5 hrs \pm 1 second. A further check was made by triangulation techniques from the information recorded by the various sensors.

An analysis of the seismic recording, together with the radar, ATC and radar information is contained in Appendix C.

1.17.3 Trajectory analysis

A detailed trajectory analysis was carried out by Cranfield Institute of Technology in an effort to provide a sequence for the aircraft disintegration. This analysis comprised several separate processes, including individual trajectory calculations for a limited number of key items of wreckage and mathematical modelling of trajectory paths adopted by a series of hypothetical items of wreckage encompassing the drag/weight spectrum of the actual wreckage.

The work carried out at Cranfield enabled the reasons for the two separate trails to be established. The narrow northern trail was shown to be created by debris released from the aircraft in a vertical dive between 19,000 and 9,000 feet overhead Lockerbie. The southern trail, longer and straight for most of its length, appeared to have been created by wreckage released during the initial disintegration at altitude whilst the aircraft was in level flight. Those items falling closest to Lockerbie would have been those with higher density which would travel a significant distance along track before losing all along-track velocity, whilst only drifting a small distance downwind, owing to the high speed of their descent. The most westerly items thus showed the greatest such effect. The southern trail therefore had curved boundaries at its western end with the curvature becoming progressively less to the east until the wreckage essentially fell in a straight band. Thus wreckage in the southern trail positioned well to the east could be assumed to have retained

negligible velocity along aircraft track after separation and the along-track distribution could be used to establish an approximate sequence of initial disintegration.

The analysis calculated impact speeds of 120 kts for the nose section weighing approximately 17,500 lb and 260 kts for the engines and pylons which each weighed about 13,500 lb. Based on the best available data at the time, the analysis showed that the wing (approximately 100,000 lb of structure containing an estimated 200,000 lb of fuel) could have impacted at a speed, in theory, as high as 650 kts if it had 'flown' in a streamlined attitude such that the drag coefficient was minimal. However, because small variations of wing incidence (and various amounts of attached fuselage) could have resulted in significant increases in drag coefficient, the analysis also recognized that the final impact speed of the wing could have been lower.

1.17.4 Space debris re-entry

Four items of space debris were known to have re-entered the Earth's atmosphere on 21 December 1988. Three of these items were fragments of debris which would not have survived re-entry, although their burn up in the upper atmosphere might have been visible from the Earth's surface. The fourth item landed in the USSR at 09.50 hrs UTC.

2 ANALYSIS

2.1 Introduction

The airport security and criminal aspects of the destruction of Boeing 747 registration N739PA near Lockerbie on 21 December 1988 are the subjects of a separate investigation and are not covered in this report. This analysis discusses the technical aspects of the disintegration of the aircraft and considers possible ways of mitigating the effects of an explosion in the future.

2.2 Explosive destruction of the aircraft

The geographical position of the final secondary return at 19.02:46.9 hrs was calculated by RSRE to be OS Grid Reference 15257772, annotated Point A in Appendix B, Figure B-4, with an accuracy considered to be better than ± 300 metres. This return was received 3.1 ± 1 seconds before the loud sound was recorded on the CVR at 19.02:50 hrs. By projecting from this position along the track of 321° (Grid) for 3.1 ± 1 seconds at the groundspeed of 434 kts, the position of the aircraft was calculated to be OS Grid Reference 14827826, annotated Point B in Appendix B, Figure B-4, within an accuracy of ± 525 metres. Based on the evidence of recorded data only, Point B therefore represents the geographical position of the aircraft at the moment the loud sound was recorded on the CVR.

The datum line, discussed at paragraph 1.12.1.6, was derived from a detailed analysis of the distribution of specific items of wreckage, including those exhibiting positive evidence of a detonating high performance plastic explosive. The scatter of these items about the datum line may have been due partly to velocities imparted by the force of the detonating explosive and partly by the difficulty experienced in pinpointing the location of the wreckage accurately in relatively featureless terrain and poor visibility. However, the random nature of the scatter created by these two effects would have tended to counteract one another, and a major error in any one of the eleven grid references would have had little overall effect on the whole line. There is, therefore, good reason to have confidence in the validity of the datum line.

The items used to define the datum line, included those exhibiting positive evidence of a detonating

high performance plastic explosive, would have been the first pieces to have been released from the aircraft. The datum line was projected westwards until it intersected the known radar track of the aircraft in order to derive the position of the aircraft along track at which the explosive items were released and therefore the position at which the IED had detonated. This position was OS grid reference 146786 and is annotated Point C in Appendix B, Figure B-4. Point C was well within the circle of accuracy (± 525 metres) of the position at which the loud noise was heard on the CVR (Point B). There can, therefore, be no doubt that the loud noise on the CVR was directly associated with the detonation of the IED and that this explosion initiated the disintegration process and directly caused the loss of the aircraft.

2.3 Flight recorders

2.3.1 Digital flight data recordings

A working group of the European Organisation for Civil Aviation Electronics (EUROCAE) was, during the period of the investigation, formulating new standards (Minimum Operational Performance Requirement for Flight Data Recorder Systems, Ref:- ED55) for future generation flight recorders which would have permitted delays between parameter input and recording (buffering) of up to ϵ second. These standards are intended to form the basis of new CAA specifications for flight recorders and may be adopted worldwide.

The analysis of the recording from the DFDR fitted to N739PA, which is detailed in Appendix C, showed that the recorded data simply stopped. Following careful examination and correlation of the various sources of recorded information, it was concluded that this occurred because the electrical power supply to the recorder had been interrupted at 19.02:50 hrs ± 1 second. Only 17 bits of data were not recoverable (less than 23 milliseconds) and it was not possible to establish with any certainty if this data was from the accident flight or was old data from a previous recording.

The analysis of the final data recorded on the DFDR was possible because the system did not buffer the incoming data. Some existing recorders use a process whereby data is stored temporarily in a memory device (buffer) before recording. The data within this buffer is lost when power is removed from the recorder and in currently designed recorders this may mean that up to 1.2 seconds of final data contained within the buffer is lost. Due to the necessary processing of the signals prior to input to the recorder, additional delays of up to 300 milliseconds may be introduced. If the accident had occurred when the aircraft was over the sea, it is very probable that the relatively few small items of structure, luggage and clothing showing positive evidence of the detonation of an explosive device would not have been recovered. However, as flight recorders are fitted with underwater location beacons, there is a high probability that they would have been located and recovered. In such an event the final milliseconds of data contained on the DFDR could be vital to the successful determination of the cause of an accident whether due to an explosive device or other catastrophic failure. Whilst it may not be possible to reduce some of the delays external to the recorder, it is possible to reduce any data loss due to buffering of data within the data acquisition unit.

It is, therefore, recommended that manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and hence recoverable after power loss. Although the recommendation on this aspect, made to the EUROCAE working group during the investigation, was incorporated into ED55, it is also recommended that Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.

2.3.2 Cockpit voice recorders

The analysis of the cockpit voice recording, which is detailed in Appendix C, concluded that there were valid signals available to the CVR when it stopped at 19:02:50 hrs ± 1 second because the power supply to the recorder was interrupted. It is not clear if the sound at the end of the recording is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case. In order to respond to events that result in the almost immediate loss of the aircraft's electrical power supply it was therefore recommended during the investigation that the regulatory authorities consider requiring CVR systems to contain a short duration (i.e. no greater than 1 minute) back-up power supply.

2.3.3 Detection of explosive occurrences

In the aftermath of the Air India Boeing 747 accident (AI 182) in the North Atlantic on 23 June 1985, RARDE were asked informally by AAIB to examine means of differentiating, by recording violent cabin pressure pulses, between the detonation of an explosive device within the cabin (positive pulse) and a catastrophic structural failure (negative pulse). Following the Lockerbie disaster it was considered that this work should be raised to a formal research project. Therefore, in February 1989, it was recommended that the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems. This recommendation was accepted.

Preliminary results from the trials indicate that, if a suitable sensor can be developed, its output will need to be recorded in real time and therefore it may require wiring to the CVR installation. This will further strengthen the requirement for battery back up of the CVR electrical power supply.

2.4 IED position within the aircraft

From the detailed examination of the reconstructed luggage containers, discussed at paragraph 1.12.2.4 and in Appendix F, it was evident that the IED had been located within a metal container (serial number AVE 4041 PA), near its aft outboard quarter as shown in Appendix F, Figure F-13. It was also clear that the container was loaded in position 14L of the forward hold which placed the explosive charge approximately 25 inches inboard from the fuselage skin at frame 700. There was no evidence to indicate that there was more than one explosive charge.

2.5 Engine evidence

To produce the fan blade tip rub damage noted on all engines by means of airflow inclined to the axes of the nacelles would have required a marked nose down change of aircraft pitch attitude combined with a roll rate to the left while all of the engines were attached to the wing.

The shingling damage noted on the fan blades of No 2 engine can only be attributed to airflow disturbance caused by ingestion related fan blade damage occurring when substantial power was being delivered. This is readily explained by the fact that No 2 engine intake is positioned some 27 feet aft and 30 feet outboard of the site of the explosion and that the interior of the intake exhibited a number of prominent paint smears and general foreign object damage. This damage included evidence of a strike by a cable similar to that forming part of the closure curtain of a typical baggage container. It is inconceivable that an independent blade failure could have occurred in the short time frame of this event. By similar reasoning, the absence of such shingling damage on

blades of No 3 engine was a reliable indication that it suffered no ingestion until well into the accident sequence.

The combination of the position of the explosive device and the forward speed of the aircraft was such that significant sized debris resulting from the explosion would have been available to be ingested by No 2 engine within milliseconds of the explosion. In view of the fact that the tip rub damage observed on the fan case of No 2 engine is of similar magnitude to that observed on the other three engines it is reasonable to deduce that a manoeuvre of the aircraft occurred before most of the energy of the No 2 engine fan was lost due to the effect of ingestion (seen only in this engine). Since this shingling effect could only readily be produced as a by-product of ingestion whilst delivering considerable power, it is reasonable to assume that this was also occurring before loss of major fan energy due to tip rubbing took place. Hence both phenomena must have been occurring simultaneously, or nearly so, to produce the effects observed and must have occupied a time frame of substantially less than 5 seconds. The onset of this time period would have been the time at which debris from the explosion first inflicted damage to fan blades in No 3 engine and, since the fan is only approximately 40 feet from the location of the explosive device, this would have been an insignificant time interval after the explosion.

It was therefore concluded from this evidence that the wing with all of the engines attached had achieved a marked nose down and left roll attitude change well within 5 seconds of the explosion.

2.6 Detachment of forward fuselage

Examination of the three major structural elements either side of the region of station 800 on the right side of the fuselage makes it clear that to produce the curvature of the window belt and peeling of the riveted joint at the R2 door aperture requires the door pillar to be securely in position and able to react longitudinal and lateral loads. This in turn requires the large section of fuselage on the right side between stations 760 and 1000 (incorporating the right half of the floor) to be in position in order to locate the lower end of the door pillar. Thus both these sections must have been in position until the section from station 560 to 800 (right side) had completed its deflection to the right and peeled from the door pillar. Separation of the forward fuselage must thus have been complete by the time all three items mentioned above had fallen free.

2.7 Speed of initial disintegration

The distribution of wreckage in the bands between the datum line and the 250, 300, 600 and 900 metre lines was examined in detail. The positions of these items of structure on the aircraft are shown in Appendix B, Figures B-10 to B-13. It should be noted that the position on the ground of these items, although separated by small distances when measured in a direction along aircraft track, were distributed over large distances when measured along the wreckage trail. All were recovered from positions far enough to the east to be in that part of the southern trail which was sufficiently close, theoretically, to a straight line for any curvature effect to be neglected.

The wreckage found in each of the bands enabled an approximate sequence of break-up to be established. It was clear that as the distance travelled from the datum line increased, items of wreckage further from the station of the IED were encountered. The items shown on the diagram as falling on the 250 metre band also include those fragments of lower forward fuselage skin having evidence of explosive damage and presumed to have separated as a direct result of the blast. However, a few portions of the upper forward fuselage were also found within the 250 metre band, suggesting that these items had also separated as a result of the blast.

By the time the 300 metre line was reached much of the structure from the right side in the region of the explosive device had been shed. This included the area of window belt, referred to in paragraph 2.6 above, which gave clear indications that the forward structure had detached to the right and finally peeled away at station 800. It also included the areas of adjacent structure immediately to the rear of station 800 about which the forward structure would have had to pivot. By the time the 600 metre line was reached, there was clearly insufficient structure left to connect the forward fuselage with the remainder of the aircraft. Wreckage between the 600 and 900 metre lines consisted of structure still further from the site of the IED.

There is evidence that a manoeuvre occurred at the time of the explosion which would have produced a significant change of the aircraft's flight path, however, it is considered that the change in the horizontal velocity component in the first few seconds would not have been great. The original groundspeed of the aircraft was therefore used in conjunction with the distribution of wreckage in the successive bands to establish an approximate time sequence of break-up of the forward fuselage. Assuming the original ground speed of 434 Kts, the elapsed flight times from the datum to each of the parallel lines were calculated to be:

Distance (metres)	250	300	600	900
Time (seconds)	1.1	1.3	2.7	4.0

Thus, there is little doubt that separation of the forward fuselage was complete within 2 to 3 seconds of the explosion.

The separate assessment of the known grid references of tailplane and elevator wreckage in the southern trail revealed that those items were evenly distributed about the 600 metre line and therefore that most of the tailplane damage occurred after separation of the forward fuselage was complete.

2.8 The manoeuvre following the explosion

The engine evidence, timing and mode of disintegration of the fuselage and tailplane suggests that the latter did not sustain significant damage until the forward fuselage disintegration was well advanced and the pitch/roll manoeuvre was also well under way.

Examination of the three dimensional reconstruction makes it clear that both main and upper deck floors were disrupted by the explosion. Since pitch control cables are routed through the upper deck floor beams and the roll control cables through the main deck beams, there is a strong possibility that movement of the beams under explosive forces would have applied inputs to the control cables, thus operating control surfaces in both axes.

2.9 Secondary disintegration

The distribution of fin debris between the trails suggests that disintegration of the fin began shortly before the vertical descent was established. No single mode of failure was identified and the debris which had struck the leading edge had not caused major disruption. The considerable fragmentation of the thick panels of the aft torque box was also very different from that noted on the corresponding structure of the tailplanes. It was therefore concluded that the mode of failure was probably flutter.

The finding, in the northern trail, of a slide raft wrapped around a flap track fairing suggests that at

a later stage of the disintegration the rear of the aircraft must have experienced a large angle of sideslip. The loss of the fin would have made this possible and also subjected the structure to large side loads. It is possible that such side loading would have assisted the disintegration of the rear fuselage and also have caused bending failure of the pylon attachments of the remaining three engines.

2.10 Impact speed of components

The trajectory analysis carried out by Cranfield Institute of Technology calculated impact speeds of 120 kts for the nose section, and 260 kts for the engines and pylons. These values were considered to be reliable because the drag coefficients could be estimated with a reasonable degree of confidence. Based on the best available data at the time, the analysis also showed that the wing could have impacted at a speed, in theory, as high as 650 kts if it had flown in a streamlined attitude such that the drag coefficient was minimal. However, it was also recognized that relatively small changes in the angle of incidence of the wing would have produced a significant increase in drag with a consequent reduction in impact speed. Refinement of timing information and radar data subsequent to the Cranfield analysis has enabled a revised estimate to be made of the mean speed of the wing during the descent.

The engine evidence indicated that there had been a large nose down attitude change of the aircraft early in the event. The Cranfield analysis also showed that the rear fuselage had disintegrated while essentially in a vertical descent between 19,000 and 9,000 feet over Lockerbie. Assuming that, following the explosion, the wing followed a straight line descending flight profile from 31,000 feet to 19,000 feet directly overhead Lockerbie and then descended vertically until impact, the wing would have travelled the minimum distance practicable. The ground distance between the geographical position at which the disintegration started (Figure B-4, Point B) and the crater made by the wing impact was 2997 ± 525 metres (9833 ± 1722 feet). The time interval between the explosion and the wing impact was established in Appendix C as 46.5 ± 2 seconds. Based on the above times and distances the mean linear speed achieved by the wing would have been about 440 kts.

The impact location of Nos 1, 2, and 4 engines closely grouped in Lockerbie was consistent with their nearly vertical fall from a point above the town. If they had separated at about 19,000 feet and the wing had then flown as much as one mile away from the overhead position before tracking back to impact, the total flight path length of the wing would not have required it to have achieved a mean linear speed in excess of 500 kts.

Any speculation that the flight path of the wing could have been longer would have required it to have undergone manoeuvres at high speed in order to arrive at the 19,000 feet point. The manoeuvres involved would almost certainly have resulted in failure of the primary wing structure which, from distribution of wing debris, clearly did not occur. Alternatively the wing could have travelled more than one mile from Lockerbie after reaching the 19,000 feet point, but this was considered unlikely. It is therefore concluded that the mean speed of the wing during the descent was in the region of 440 to 500 kts.

2.11 Sequence of disintegration

Analysis of wreckage in each of the bands, taken in conjunction with the engine evidence and the three-dimensional reconstruction, suggests the following sequence of disintegration:

- (i) The initial explosion triggered a sequence of events which effectively destroyed the structural integrity of the forward fuselage. Little more than remained between stations 560 and 760 (approximately) than the window belts and the cabin sidewall structure immediately above and below the windows, although much of the cargo-hold floor structure appears to have remained briefly attached to the aircraft. [Appendix B, Figure B-24]
- (ii) The main portion of the aircraft simultaneously entered a manoeuvre involving a marked nose down and left roll attitude change, probably as a result of inputs applied to the flying control cables by movement of structure.
- (iii) Failure of the left window belt then occurred, probably in the region of station 710, as a result of torsional and bending loads on the fuselage imparted by the manoeuvre (i.e. the movement of the forward fuselage relative to the remainder of the aircraft was an initial twisting motion to the right, accompanied by a nose up pitching deflection).
- (iv) The forward fuselage deflected to the right, pivoting about the starboard window belt, and then peeled away from the structure at station 800. During this process the lower nose section struck the No 3 engine intake causing the engine to detach from its pylon. This fuselage separation was apparently complete within 3 seconds of the explosion.
- (v) Structure and contents of the forward fuselage struck the tail surfaces contributing to the destruction of the outboard starboard tailplane and causing substantial damage to the port unit. This damage occurred approximately 600 metres track distance after the explosion and therefore appears to have happened after the fuselage separation was complete.
- (vi) Fuselage structure continued to break away from the aircraft and the separated forward fuselage section as they descended.
- (vii) The aircraft maintained a steepening descent path until it reached the vertical in the region of 19,000 feet approximately over the final impact point. Shortly before it did so the tail fin began to disintegrate.
- (viii) The mode of failure of the fin is not clear, however, flutter of its structure is suspected.
- (ix) Once established in the vertical dive, the fin torque box continued to disintegrate, possibly permitting the remainder of the aircraft to yaw sufficiently to cause side load separation of Nos 1, 2 and 4 engines, complete with their pylons.
- (x) Break-up of the rear fuselage occurred during the vertical descent, possibly as a result of loads induced by the yaw, leaving a section of cabin floor and baggage hold from approximately stations 1241 to 1920, together with 3 landing gear units, to fall into housing at Rosebank Terrace.
- (xi) The main wing structure struck the ground with a high yaw angle at Sherwood Crescent.

2.12 Explosive mechanisms and the structural disintegration

The fracture and damage pattern analysis was mainly of an interpretive nature involving interlocking pieces of subtle evidence such as paint smears, fracture and rivet failure characteristics, and other complex features. In the interests of brevity, this analysis will not discuss the detailed interpretation of individual fractures or damage features. Instead, the broader 'damage picture' which emerged from the detailed work will be discussed in the context of the explosive mechanisms which might have produced the damage, with a view to identifying those features of greatest significance.

It is important to keep in mind that whilst the processes involved are considered and discussed separately, the timescales associated with shock wave propagation and the high velocity gas flows are very short compared with the structural response timescales. Consequently, material which was shattered or broken by the explosive forces would have remained in place for a sufficiently long time that the structure can be considered to have been intact throughout much of the period that these explosive propagation phenomena were taking place.

2.12.1 Direct blast effect

2.12.1.1 Shock wave propagation

The direct effect of the explosive detonation within the container was to produce a high intensity spherically propagating shock wave which expanded from the centre of detonation close to the side of the container, shattering part of the side and base of the container as it passed through into the gap between the container and the fuselage skin. In breaking out of the container, some internal reflection and Mach stem interaction would have occurred, but this would have been limited by the absorptive effect of the baggage inboard, above, and forward of the charge. The force of the explosion breaking out of the container would therefore have been directed downwards and rearwards.

The heavy container base was distorted and torn downwards, causing buckling of the adjoining section of frame 700, and the container sides were blasted through and torn, particularly in the aft lower corner. Some of the material in the direct path of the explosive pressure front was reduced to shrapnel sized pieces which were rapidly accelerated outwards behind the primary shock front. Because of the overhang of the container's sloping side, fragments from both the device itself and the container wall impacted the projecting external flange of the container base edge member, producing micro cratering and sooting. Metallurgical examination of the internal surfaces of these craters identified areas of melting and other features which were consistent only with the impact of very high energy particles produced by an explosion at close quarters. Analysis of material on the crater surfaces confirmed the presence of several elements and compounds foreign to the composition of the edge member, including material consistent with the composition of the sheet aluminium forming the sloping face of the container.

On reaching the inner surface of the fuselage skin, the incident shock wave energy would partially have been absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of its energy would have been transmitted, as a shock wave, through the skin and into the atmosphere [Appendix B, Figure B-25], but a significant amount of energy would have been returned as a reflected shock wave, back into the cavity between the container and the fuselage skin where Mach stem shock waves would have been formed. Evidence of rapid shattering was found in a region approximately bounded by frames 700 & 720 and stringers 38L & 40L, together with the lap joint at 39L.

The shattered fuselage skin would have taken a significant time to move, relative to the timescales associated with the primary shock wave propagation. Clear evidence of soot and small impact craters were apparent on the internal surfaces of all fragments of container and structure from the shatter zone, confirming that the this material had not had time to move before it was hit by the cloud of shrapnel, unburnt explosive residues and sooty combustion products generated at the seat of the explosion.

Following immediately behind the primary shock wave, a secondary high pressure wave - partly caused by reflections off the baggage behind the explosive material but mainly by the general pressure rise caused by the chemical conversion of solid explosive material to high temperature gas - emerged from the container. The effect of this second pressure front, which would have been more sustained and spread over a much larger area, was to cause the fuselage skin to stretch and blister outwards before bursting and petalling back in a star-burst pattern, with rapidly running tear fractures propagating away from a focus at the shatter zone. The release of stored energy as the skin ruptured, combined with the outflow of high pressure gas through the aperture, produced a characteristic curling of the skin 'petals' - even against the slipstream. For the most part, the skins

which petalled back in this manner were torn from the frames and stringers, but the frames and stringers themselves were also fractured and became separated from the rest of the structure, producing a very large jagged hole some 5 feet longitudinally by 17 feet circumferentially (upwards to a region just below the window belt and downwards virtually to the centre line).

From this large jagged hole, three of the fractures continued to propagate away from the hole instead of terminating at the boundary. One fracture propagated longitudinally rearwards as far as the wing cut-out and another forwards to station 480, creating a continuous longitudinal fracture some 43 feet in length. A third fracture propagated circumferentially downwards along frame 740, under the belly, and up the right side of the fuselage almost as far as the window belt - a distance of approximately 23 feet.

These extended fractures all involved tearing or related failure modes, sometimes exploiting rivet lines and tearing from rivet hole to rivet hole, in other areas tearing along the full skin section adjacent to rivet lines, but separate from them. Although the fractures had, in part, followed lap joints, the actual failure modes indicated that the joints themselves were not inherently weak, either as design features or in respect of corrosion or the conditions of the joints on this particular aircraft.

Note: The cold bond process carried out at manufacture on the lap joints had areas of disbonding prior to the accident. This disbonding is a known feature of early Boeing 747 aircraft which, by itself, does not detract from the structural integrity of the hull. The cold bond adhesive was used to improve the distribution of shear load across the joint, thus reducing shear transfer via the fasteners and improving the resistance of the joint to fatigue damage; the fasteners were designed to carry the full static loading requirements of the joint without any contribution from the adhesive. Thus, the loss of the cold bond integrity would only have been significant if it had resulted in the growth of fatigue cracks, or corrosion induced weaknesses, which had then been exploited by the explosive forces. No evidence of fatigue cracking was found in the bonded joints. Inter-surface corrosion was present on most lap joints but only one very small region of corrosion had resulted in significant material thinning; this was remote from the critical region and had not played any part in the break-up.

The cracks propagating upwards as part of the petalling process did not extend beyond the window line. The wreckage evidence suggests that the vertical fractures merged, effectively closing off the fracture path to produce a relatively clean bounding edge to the upper section of the otherwise jagged hole produced by the petalling process. There are at least two probable reasons for this. Firstly the petalling fractures above the shattered zone did not diverge, as they had tended to do elsewhere. Instead, it appears that a large skin panel separated and peeled upwards very rapidly producing tears at each side which ran upwards following almost parallel paths. However, there are indications that by the time the fractures had run several feet, the velocity of fracture had slowed sufficiently to allow the free (forward) edge of the skin panel to overtake the fracture fronts, as it flexed upwards, and forcibly strike the fuselage skin above, producing clear witness marks on both items. Such a tearing process, in which an approximately rectangular flap of skin is pulled upwards away from the main skin panel, is likely to result in the fractures merging. Secondly, this merging tendency would have been reinforced in this particular instance by the stiff window belt ahead of the fractures, which would have tended to turn the fractures towards the horizontal.

It appears that the presence of this initial ('clean') hole, together with the stiff window belt above, encouraged other more slowly running tears to break into it, rather than propagating outwards away from the main hole.

2.12.1.2 Critical crack considerations

The three very large tears extending beyond the boundary of the petalled region resulted in a critical reduction of fuselage structural integrity.

Calculations were carried out at the Royal Aerospace Establishment to determine whether these fractures, growing outwards from the boundary of the petalled hole, could have occurred purely as a result of normal differential pressure loading of the fuselage, or whether explosive forces were required in addition to the pressurisation loads.

Preliminary calculations of critical crack dimensions for a fuselage skin punctured by a 20 by 20 inches jagged hole indicated that unstable crack growth would not have occurred unless the skin stress had been substantially greater than the stress level due to normal pressurisation loads alone. It was therefore clear that explosive overpressure must have produced the gross enlargement of the initially small shattered hole in the hull. Furthermore, it was apparent from the degree of curling and petalling of the skin panels within the star-burst region that this overpressure had been relatively long term, compared with the shock wave overpressure which had produced the shatter zone. A more refined analysis of critical crack growth parameters was therefore carried out in which it was assumed that the long term explosive overpressure was produced by the chemical conversion of solid explosive material into high temperature gas.

An outline of the fracture propagation analysis is given at Appendix D. This analysis, using theoretical fracture mechanics, showed that, after the incident shock wave had produced the shatter zone, significant explosive overpressure loads were needed to drive the star-burst fractures out to the boundary of the petalled skin zone. Thereafter, residual gas overpressure combined with fuselage pressurisation loads were sufficient to produce the two major longitudinal cracks and a single major circumferential crack, extending from the window belt down to beyond the keel centreline.

2.12.1.3 Damage to the cabin floor structure

The floor beams in the region immediately above the baggage container in which the explosive had detonated were extensively broken, displaying clear indications of overload failure due to buckling caused by localised upward loading of the floor structure.

No direct evidence of bruising was found on the top panel of the container. It therefore appears that the container did not itself impact the floor beams, but instead the floor immediately above the container was broken through as a result of explosive overpressure as gases emerged from the ruptured container and loaded the floor panels. Data on floor strengths, provided by Boeing, indicated that the cabin floor (with the CRAF modification) would fail at a uniform static differential pressure of between 3.5 and 3.9 psi (high pressure below the cabin floor), and that the floor panel to floor beam attachments would not fail before the floor beams. Whilst there is no direct evidence of the pressure loading on the floor structure immediately following detonation, there can be no doubt that in the region of station 700 it would have exceeded the ultimate failure load by a large margin.

2.12.2 Indirect explosive damage (damage at remote sites)

All of the damage considered in the foregoing analysis, and the mechanisms giving rise to that damage, resulted from the direct impact of explosive shock waves and/or the short-term explosive

overpressure on structure close to the source of the explosion. However, there were several regions of skin separation at sites remote from the explosion (see para 1.12.3.2) which were much more difficult to understand. These remote sites formed islands of indirect explosive damage separated from the direct damage by a sea of more generalised structural failure characterised by the progressive aerodynamic break-up of the weakened forward fuselage. All of these remote damage sites were consistent with the impact of very localised pressure impulses on the internal surfaces of the hull -effectively high energy 'pressure blows' against the inner surfaces produced by explosive shock waves and/or high pressure gas flows travelling through the interior spaces of the hull.

The propagation of explosive shock waves and supersonic gas flows within multiple, interlinking, cavities having indeterminate energy absorption and reflection properties, and ill-defined structural response, is extremely complex. Work has been initiated in an attempt to produce a three-dimensional computer analysis of the shock wave and supersonic flow propagation inside the fuselage, but full theoretical analysis is beyond present resources.

Because of the complexity of the problem, the following analysis will be restricted to a qualitative consideration of the processes which were likely to have taken place. Whilst such an approach is necessarily limited, it has identified a number of propagation mechanisms which appear to have been of fundamental importance to the break-up of Flight PA103, and which are likely to be critical in any future incident involving the detonation of high explosive inside an aircraft hull.

2.12.2.1 Shock wave propagation through internal cavities

When Mach stem shocks are produced not only are the shock pressures very high but they propagate at very high velocity parallel to the reflecting surface. In the context of the lower fuselage structure in the region of Mach stem formation, it can readily be seen that the Mach stem will be perfectly orientated to enter the narrow cavity formed between the outer skin and the cargo liner/containers, bounded by the fuselage frames [Appendix B, Figure B-25]. This cavity enables the Mach stem shock wave to propagate, without causing damage to the walls (due to the relatively low pressure where the Mach stem sweeps their surface), and reach regions of the fuselage remote from the source of the explosion. Furthermore, energy losses in the cavity are likely to be less than would occur in the 'free' propagation case, resulting in the efficient transmission of explosive energy. The cavity would tend to act like a 'shock tube', used for high speed aerodynamic research, confining the shock wave and keeping it running along the cavity axis, with losses being limited to kinetic heating due to friction at the walls.

Paragraph 1.6.3 contains a general description of the structural arrangements in the area of the cargo hold. Before proceeding further and considering how the shock waves might have propagated through this network of cavities, it should be pointed out that the timescale associated with the propagation of the shock waves is very short compared with the timescale associated with physical movement and separation of skin and structure fractured or damaged by the shock. Therefore, for the purpose of assessing the shock propagation through the cavities, the explosive damage to the hull can be ignored and the structure regarded as being intact. A further simplification can usefully be made by considering the structure to be rigid. This assumption would, if the analysis were quantitative, result in over-estimations of the shock strengths. However, for the purposes of a purely qualitative assessment, the assumption should be valid, in that the general trends of behaviour should not be materially altered.

It has already been argued that the shock wave emerging from the container was, in part, reflected back off the inner surface of the fuselage skin, forming a Mach stem shock wave which would then have tended to travel into the semi-circular lower lobe cavity. The Mach stem waves would

have propagated away through this cavity in two directions:

- (i) under the belly, between the frames [Appendix B, Figure B-3, detail A], and
- (ii) up the left side, expanding into the cavity formed by the longitudinal manifold chamber where it joins the lower lobe cavity.

As the shock waves travelled along the cavity, little attenuation or other change of characteristic was likely to have occurred until the shocks passed the entrances to other cavities, or impinged upon projections and other local changes in the cavity. A review of the literature dealing with propagation of blast waves within such cavities provides useful insights into some of the physical mechanisms involved.

As part of a research program carried out into the design of ventilation systems for blast hardened installations intended to survive the long duration blast waves following the detonation of nuclear weapons, the propagation of blast waves along the primary passages and into the side branches of ventilation ducts was studied. The research showed that 90° bends in the ducts produced very little attenuation of shock wave pressure; a series of six right angle bends produced only a 30% pressure attenuation, together with an extension of the shock duration. It is therefore evident that the attenuation of shock waves propagating through the fuselage cavities, all of which were short with hardly any right angle turns, would have been minimal.

It was also demonstrated that secondary shock waves develop within the entrance to any side branch from the main duct, produced by the interaction of the primary shock wave with the geometric changes in the duct walls at the side-branch location. These secondary shock waves interact as they propagate into the side branch, combining together within a relatively short distance (typically 7 diameters) to produce a single, plane shock wave travelling along the duct axis. In a rigid, smooth walled structure, this mechanism produces secondary shock overpressures in the side branch of between 30% and 50% of the value of the primary shock, together with a corresponding attenuation of the primary shock wave pressure by approximately 20% to 25%.

This potential for the splitting up and re-transmission of shock wave energy within the lower hull cavities is of extreme importance in the context of this accident. Though the precise form of the interactions is too complex to predict quantitatively, it is evident that the lower hull cavities will serve to convey the overpressure efficiently to other parts of the aircraft. Furthermore, the cavities are not of serial form, i.e. they do not simply branch (and branch again) in a divergent manner, but instead form a parallel network of short cavities which reconnect with each other at many different points, principally along the crease beams. Thus, considerable scope exists for: the additive recombination of blast waves at cavity junctions; for the sustaining of the shock overpressure over a greater time period; and, for the generation of multiple shocks produced by the delay in shock propagation inherent in the different shock path (i.e. cavity) lengths.

Whilst it has not been possible to find a specific mechanism to explain the regions of localised skin separation and peel-back (i.e. the 'pressure blow' regions referred to in para 2.12.2), they were almost certainly the result of high intensity shock overpressures produced locally in those regions as a result of the additive recombination of shock waves transmitted through the lower hull cavities. It is considered that the relatively close proximity of the left side region of damage just below floor level at station 500, [Appendix B, Figure B-19, region D] to the forward end of the cargo hold may be significant insofar as the reflections back from the forward end of the hold would have produced a local enhancement of the shock overpressure. Similarly, 'end blockage effects' produced by the cargo door frame might have been responsible for local enhancements in the area of the belly skin separation and curl-back at station 560 [Appendix B, Figure B-19 and B-

20, region E].

The separation of the large section of upper fuselage skin [Appendix B, Figure B-19 and B-20, detail B] was almost certainly associated with a local overpressure in the side cavities between the main deck window line and the upper deck floor, where the cavity is effectively closed off. It is considered that the most probable mechanism producing this region of impulse overpressure was a reflection from the closed end of the cavity, possibly combined with further secondary reflections from the window assembly, the whole being driven by reflective overpressures at the forward end of the longitudinal manifold cavity caused by the forward end of the cargo hold. The local overpressure inside the sidewall cavity would have been backed up by a general cabin overpressure resulting from the floor breakthrough, giving rise to an increased pressure acting on the inner face of the cabin side liner panels. This would have provided pseudo mass to the panels, effectively preventing them from moving inwards and allowing them to react the impulse pressure within the cavity, producing the region of local high pressure evidenced by the region of quilting on the skin panels [Appendix B, Figure B-19, region C].

2.12.2.2 Propagation of shock waves into the cabin

The design of the air-conditioning/depressurisation-venting systems on the Boeing 747 (and on most other commercial aircraft) is seen as a significant factor in the transmission of explosive energy, as it provides a direct connection between the main passenger cabin and the lower hull at the confluence of the lower hull cavities below the crease beam. The floor level air conditioning vents along the length of the cabin provided a series of apertures through which explosive shock waves, propagating through the sub floor cavities, would have radiated into the main cabin.

Once the shock waves entered the cabin space, the form of propagation would have been significantly different from that which occurred in the cavities in the lower hull. Again, the precise form of such radiation cannot be predicted, but it is clear that the energy would potentially have been high and there would also (potentially) have been a large number of shock waves radiating into the cabin, both from individual vents and in total, with further potential to recombine additively or to 'follow one another up' producing, in effect, sustained shock overpressures.

Within the cabin, the presence of hard, reflective, surfaces are likely to have been significant. Again, the precise way in which the shock waves interacted is vastly beyond the scope of current analytical methods and computing power, but there clearly was considerable potential for additive recombination of the many different shock waves entering at different points along the cabin and the reflected shock waves off hard surfaces in the cabin space, such as the toilet and galley compartments and overhead lockers. These recombination effects, though not understood, are known phenomena. Appendix B, Figure B-26 shows how shock waves radiating from floor level might have been reflected in such a way as produce shock loading on a localised area of the pressure hull.

2.12.2.3 Supersonic gas flows

The gas produced by the explosive would have resulted in a supersonic flow of very high pressure gas through the structural cavities, which would have followed up closely behind the shock waves. Whilst the physical mechanisms of propagation would have been different from those of the shock wave, the end result would have been similar, i.e. there would have been propagation via multiple, linked paths, with potential for additive recombination and successive pressure pulses resulting

from differing path lengths. Essentially, the shock waves are likely to have delivered initial 'pressure blows' which would then have been followed up immediately by more sustained pressures resulting from the high pressure supersonic gas flows.

2.13 Potential limitation of explosive damage

Quite clearly the detonation of high explosive material anywhere on board an aircraft is potentially catastrophic and the most effective means of protecting lives is to stop such material entering the aircraft in the first place. However, it is recognised that such risks cannot be eliminated entirely and it is therefore essential that means are sought to reduce the vulnerability of commercial aircraft structures to explosive damage.

The processes which take place when an explosive detonates inside an aircraft fuselage are complex and, to a large extent, fickle in terms of the precise manner in which the processes occur. Furthermore, the potential variation in charge size, position within the hull, and the nature of the materials in the immediate vicinity of the charge (baggage etc) are such that it would be unrealistic to expect to neutralise successfully the effect of every potential explosive device likely to be placed on board an aircraft. However, whilst the problem is intractable so far as a total solution is concerned, it should be possible to limit the damage caused by an explosive device inside a baggage container on a Boeing 747 or similar aircraft to a degree which would allow the aircraft to land successfully, albeit with severe local damage and perhaps resulting in some loss of life or injuries.

In Appendix E the problem of reducing the vulnerability of commercial aircraft to explosive damage is discussed, both in general terms and in the context of aircraft of similar size and form to the Boeing 747. In that discussion, those damage mechanisms which appear to have contributed to the catastrophic structural failure of Flight PA103 are identified and possible ways of reducing their damaging effects are suggested. These suggestions are intended to stimulate thought and discussion by manufacturers, airworthiness authorities, and others having an interest in finding solutions to the problem; they are intended to serve as a catalyst rather than to lay claim to a definitive solution.

2.14 Summary

It was established that the detonation of an IED, loaded in a luggage container positioned on the left side of the forward cargo hold, directly caused the loss of the aircraft. The direct explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. Major cracks continued to propagate from the large hole under the influence of the service pressure differential. The indirect explosive effects produced significant structural damage in areas remote from the site of the explosion. The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage, allow the nose and flight deck area to detach within a period of 2 to 3 seconds, and subsequently allow most of the remaining aircraft to disintegrate while it was descending nearly vertically from 19,000 to 9,000 feet.

The investigation has enabled a better understanding to be gained of the explosive processes involved in such an event and to suggest ways in which the effects of such an explosion might be mitigated, both by changes to future design and also by retrospective modification of aircraft. It is therefore recommended that Regulatory Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of the aircraft structure and systems to explosive damage.

3. CONCLUSIONS

(a) Findings

- (i) The crew were properly licenced and medically fit to conduct the flight.
- (ii) The aircraft had a valid Certificate of Airworthiness and had been maintained in compliance with the regulations.
- (iii) There was no evidence of any defect or malfunction in the aircraft that could have caused or contributed to the accident.
- (iv) The structure was in good condition and the minimal areas of corrosion did not contribute to the in-flight disintegration.
- (v) One minor fatigue crack approximately 3 inches long was found in the fuselage skin but this had not been exploited during the disintegration.
- (vi) An improvised explosive device detonated in luggage container serial number AVE 4041 PA which had been loaded at position 14L in the forward hold. This placed the device approximately 25 inches inboard from the skin on the lower left side of the fuselage at station 700.
- (vii) The analysis of the flight recorders, using currently accepted techniques, did not reveal positive evidence of an explosive event.
- (viii) The direct explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. Major cracks continued to propagate from the large hole under the influence of the service pressure differential.
- (ix) The indirect explosive effects produced significant structural damage in areas remote from the site of the explosion.
- (x) The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage.
- (xi) Containers and items of cargo ejected from the fuselage aperture in the forward hold, together with pieces of detached structure, collided with the empennage severing most of the left tailplane, disrupting the outer half of the right tailplane, and damaging the fin leading edge structure.
- (xii) The forward fuselage and flight deck area separated from the remaining structure within a period of 2 to 3 seconds.
- (xiii) The No 3 engine detached when it was hit by the separating forward fuselage.
- (xiv) Most of the remaining aircraft disintegrated while it was descending nearly vertically from 19,000 to 9,000 feet.
- (xv) The wing impacted in the town of Lockerbie producing a large crater and creating a fireball.

(b) Cause

The in-flight disintegration of the aircraft was caused by the detonation of an improvised explosive device located in a baggage container positioned on the left side of the forward cargo hold at aircraft station 700.

4. SAFETY RECOMMENDATIONS

The following Safety Recommendations were made during the course of the investigation :

- 4.1 That manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and the data recoverable after power loss.
- 4.2 That Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.
- 4.3 That Airworthiness Authorities consider requiring the CVR system to contain a short

duration, i.e. no greater than 1 minute, back-up power supply to enable the CVR to respond to events that result in the almost immediate loss of the aircraft's electrical power supply.

4.4 That the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems.

4.5 That Airworthiness Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of aircraft structure and systems to explosive damage.

M M Charles
Inspector of Accidents
Department of Transport

July 1990

APPENDIX A

PERSONNEL CONDUCTING THE INVESTIGATION

The following Inspectors of the Air Accidents Investigation Branch conducted the investigation:

Mr M M Charles	Investigator-in-Charge
Mr D F King	Principal Inspector (Engineering)
Mr P F Sheppard	Assistant Principal Inspector (Engineering)
Mr A N Cable	Senior Inspector (Engineering)
Mr R G Carter	Senior Inspector (Engineering)
Mr P T Claiden	Senior Inspector (Engineering)
Mr P R Coombs	Senior Inspector (Engineering)
Mr S R Culling	Senior Inspector (Engineering)
Miss A Evans	Senior Inspector (Engineering)
Mr B M E Forward	Senior Inspector (Operations)
Mr P N Giles	Senior Inspector (Operations)
Mr S W Moss	Senior Inspector (Engineering)
Mr R Parkinson	Senior Inspector (Engineering)
Mr J D Payling	Senior Inspector (Operations)
Mr C G Pollard	Senior Inspector (Engineering)
Mr C A Protheroe	Senior Inspector (Engineering)

Mr A H Robinson	Senior Inspector (Engineering)
Mr A P Simmons	Senior Inspector (Engineering)
Mr R G Vance	Senior Inspector (Engineering)
Mr R StJ Whidborne	Senior Inspector (Operations)

The Air Accidents Investigation Branch would like to thank the following organisations from the United Kingdom, United States of America, France, and Canada who participated in the investigation:

Air Line Pilot's Association International

Boeing Commercial Airplane Company

British Airways

British Army

British Geological Survey

Bureau Enquete Accidents

Canadian Aviation Safety Bureau

Civil Aviation Authority

Cranfield Institute of Technology

Federal Aviation Administration

Federal Bureau of Investigation

Independent Union of Flight Attendants

National Transportation Safety Board

Pan American World Airways

Police Service

Royal Aerospace Establishment

Royal Air Force

Royal Armaments Research and Development Establishment

Royal Navy

Royal Ordnance

Royal Signals and Radar Establishment

United Technologies International Operations (Pratt and Whitney)

The Air Accidents Investigation Branch would also like to acknowledge the excellent work of the Dumfries & Galloway Regional Council and to thank all the many voluntary organisations who gave such unstinting support to the investigation.

APPENDIX C

ANALYSIS OF RECORDED DATA

1. Introduction

This appendix describes and analyses the different types of recorded data which were examined during the investigation of the accident to Boeing 747 registration N739PA at Lockerbie on 21 December 1988. The recorded data consists of that from the Cockpit Voice Recorder (CVR), the Digital Flight Data Recorder (DFDR), Air Traffic Control (ATC) radio telephony (RTF), ATC radar, and British Geological Survey seismic records. The time correlation of the records is also discussed.

2. Digital flight data recorder

The flight data recorder installation conformed to ARINC 573B standard with a Lockheed Model 209 DFDR receiving data from a Teledyne Controls Flight Data Acquisition Unit (FDAU). The system recorded 22 analogue parameters and 27 discrete (event) parameters. The flight recorder control panel was located in the flight deck overhead panel. The FDAU was in the main equipment centre at the front end of the forward hold and the flight recorder was mounted in the aft equipment centre.

2.1 DFDR strip and examination

Internal inspection of the DFDR showed that there was considerable disruption to the control electronics circuits. The crash protection was removed and the plastic recording tape was found detached from its various guide rollers and tangled in the tape spools. There was no tension in the negator springs. This indicated that the tape had probably moved since electrical power was removed from the recorder. The position of the tape in relation to the record/replay heads was marked with a piece of splicing tape in order to quantify the movement. To ensure that no additional damage was caused to the tape it was necessary to cut the negator springs to separate the upper and lower tape reels.

The crinkling and stretching of the tape and the damage to the control electronics meant that the tape had to be replayed outside the recorder. AAIB experience has shown that the most efficient method of replaying stretched Lockheed recorder tapes is to re-spool the tape into a known serviceable recorder, in this case a Plessey 1584G.

2.2 DFDR replay

The 25 hour duration of the DFDR was satisfactorily replayed. Data relating to the accident flight was recorded on track 2. The only significant defect in the recording system was that normal acceleration was inoperative. There was one area on the tape, 2 minutes from the end, where data synchronisation was lost for 1 second.

Decoding and reduction of the data from the accident flight showed that no abnormal behaviour of the data sensors had been recorded. The recorded data simply stopped. Figure C-1 is a graphical representation of the main flight parameters.

2.3 DFDR analysis

In order to ensure that all recorded data from the accident flight had been decoded and to examine the quality of the data at the end of the recording, a section of tape, including both the most recently recorded data and the oldest data (data from 25 hours past), was replayed through an ultra-violet (UV) strip recorder. The data was also digitised and the resulting samples used to reconstruct the tape signal on a VDU.

Both methods of signal representation were used to determine the manner by which the recorder stopped. There was no gap between the most recently recorded data and the 25 hour old data. This showed that the recorder stopped while there was an incoming data stream from the FDAU. The recorder, therefore, stopped because its electrical supply was disconnected. The tape signal was examined for any transients or noise signals that would have indicated the presence of electrical disturbances prior to the recorder stopping. None was found and this indicated that there had been a quick clean break of the electrical supply.

The last seconds of data were decoded independently using both the UV record and the digitised signal. Only 17 bits of data were not recoverable (less than 23 milliseconds) and it was not possible to establish with any certainty if this data was from the accident flight or if it was old data from a previous recording.

A working group of the European Organisation for Civil Aviation Electronics (EUROCAE) was, during the period of the investigation, formulating new standards (Minimum Operational Performance Requirement for Flight Data Recorder Systems, Ref:- ED55) for future generation flight recorders which would have permitted delays between parameter input and recording (buffering) of up to ? second. These standards are intended to form the basis of new CAA specifications for flight recorders and may be adopted worldwide.

The analysis of the final data recorded on the DFDR was possible because the system did not buffer the incoming data. Some existing recorders use a process whereby data is stored temporarily in a memory device (buffer) before recording. The data within this buffer is lost when power is removed from the recorder and in currently designed recorders this may mean that up to 1.2 seconds of final data contained within the buffer is lost. Due to the necessary processing of the signals prior to input to the recorder, additional delays of up to 300 milliseconds may be introduced. If the accident had occurred when the aircraft was over the sea, it is very probable that the relatively few small items of structure, luggage and clothing showing positive evidence of the detonation of an explosive device would not have been recovered. However, as flight recorders are fitted with underwater location beacons, there is a high probability that they would have been located and recovered. In such an event the final milliseconds of data contained on the DFDR could be vital to the successful determination of the cause of an accident whether due to an explosive device or other catastrophic failure. Whilst it may not be possible to reduce some of the delays

external to the recorder, it is possible to reduce any data loss due to buffering of data within the data acquisition unit.

It is, therefore, recommended that manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and hence recoverable after power loss. Although the recommendation on this aspect, made to the EUROCAE working group during the investigation, was incorporated into ED55, it is also recommended that Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.

3. Cockpit voice recorder (CVR)

The aircraft was equipped with a 30 minute duration 4 track Fairchild Model A100 CVR, and a Fairchild model A152 cockpit area microphone (CAM). The CVR control panel containing the CAM was located in the overhead panel on the flight deck and the recorder itself was mounted in the aft equipment centre.

The channel allocation was as follows:-

Channel 1	Flight Engineer's RTF.
Channel 2	Co-Pilot's RTF.
Channel 3	Pilot's RTF.
Channel 4	Cockpit Area Microphone.

3.1 CVR strip and examination

To gain access to the recording tape it was necessary to cut away the the outer case and saw through part of the crash protected enclosure. No damage to the tape transport or the recording tape was found. The endless loop of tape was cut and the tape transferred to the replay equipment. The electronic modules in the CVR were crushed and there was evidence of long term overheating of the dropper resistors on the power supply module. The CAM had been crushed breaking internal wiring and damaging components on the printed circuit board.

3.2 CVR replay

The erase facility within the CVR was not functioning satisfactorily and low level communications from earlier recordings was audible on the RTF channels. The CAM channel was particularly noisy, this was probably due to the combination of the inherently noisy cockpit of the B747-100 in the climb and distortion from the incomplete erasure of the previous recordings. On two occasions the crew had difficulty understanding ATC, possibly indicating high cockpit noise levels. There was a low frequency sound present at irregular intervals on the CAM track but the source of this sound could not be identified as of either acoustic or electrical in origin.

The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual in crew behaviour. The tape record ended with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording. The sound occurred whilst the crew were copying their transatlantic clearance from Shanwick ATC.

3.3 Analysis of the CVR record

3.3.1 The stopping of the recorder

To determine the mechanism that stopped the recorder a bench test rig was constructed utilizing an A100 CVR and an A152 CAM. Figures C-2 to C-5 show the effect of shorting, earthing or disconnecting the CAM signal wires. Figure C-8 shows the CAM channel signal response to the event which occurred on Flight PA103. From this it can be seen that there are no characteristic transients similar to those caused by shorting or earthing the CAM signal wires. Neither does the signal stop cleanly and quickly as shown in Figure C-5, indicating that the CAM signal wires were not interrupted. The UV trace shows the recorded signal decaying in a manner similar to that shown in Figure C-6, which demonstrates the effect of disconnecting electrical power from the recorder. The tests were repeated on other CVRs with similar results and it is therefore concluded that Flight PA103's CVR stopped because its electrical power was removed.

Figures C-9A to C-9D show the recorded signals for the Air India B747 (AI 182) accident in the North Atlantic on 23 June 1985. These show that there is a large transient on the CAM track indicating earthing or shorting of the CAM signal wires and that recorder power-down is more prolonged, indicating attempts to restore the electrical power supply either by bus switching or healing of the fault. The Flight PA103 CVR shows no attempts at power restoration with the break being clean and final.

In order to respond to events that result in the almost immediate loss of the aircraft's electrical power supply it was therefore recommended during the investigation that the regulatory authorities consider requiring CVR systems to contain a short duration (i.e. no greater than 1 minute) back-up power supply.

3.3.2 Information concerning the event

Figure C-8 is an expanded UV trace of the final milliseconds of the CVR record. Three tracks have been used, the flight engineer's RTF channel which contained similar information to the P2's channel has been replaced with a timing signal. Individual sections of interest are identified by number. On the bottom trace, the P1 RTF track, section 1 is part of the Shanwick transatlantic clearance. During this section the loud sound on the CAM channel is evident.

Examination of the DFDR event recordings shows that the Shanwick oceanic clearance was being received on VHF2, the aerial for which is on the underside of the fuselage close to the seat of the explosion. Section 2 identifies a transient, on the P1 channel, typical of an end of ATC transmission transient for this CVR. The start and finish of most of the recorded ATC transmissions were analysed and they produce a similar signature to the three shown in Figure C-10. The signature on the P1 channel more closely resembles the end of transmission signature and it is open to conjecture that this transient was caused by the explosion damaging the aerial feeder and/or its supporting structure.

Section 3 shows what is considered to be a high speed power supply transient which is evident on all the RTF channels and is probably on the CAM channel, but cannot be identified because of the automatic gain control (AGC), limiting the audio event. This transient is considered to coincide with the loss of electrical power to the CVR. Section 5 identifies the period to the end of recording and this agrees well with tests carried out by AAIB and independently by Fairchild as part of the AI 182 investigation. The typical time from removal of the electrical supply until end of recording is

110 milliseconds.

During the period identified as section 4 it is considered that the disturbances on the RTF channels are electrical transients probably channelled through the communications equipment. Section 6 identifies the 170 millisecond period from the point when the sound was first heard on the CAM until the recording stopped.

The CAM unit is of the old type which has a frequency response of 350 to 3500 Hz. The useable duration of the signal is probably confined to the first 60 milliseconds of the final 170 milliseconds and even during this period the AGC is limiting the signal. In the remaining time the sound is being distorted because power to the recorder has been disconnected. The ambient cockpit noise may have been high enough to have caused the AGC to have been active prior to the event and in this event the full volume of the sound would not be audible. Distortion from the incomplete erasure of the last recording may form part of the recorded signal.

It is not clear if the recorded sound is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case.

Additionally some of the frequencies present on the recording were not present in the original sound, but are the result of the rise in total harmonic distortion caused by the increased amplitude of the incoming signal. Outputs from a frequency analysis of the recorded signal for the same frequency of input to the CVR, but at two input amplitudes, are shown in Figures C-11 and C-12. These illustrate the effects on harmonic distortion as the signal level is increased. Finally the recorded signal does not lend itself to analysis by a digital spectrum analyser as it is, in a large measure, aperiodic and most digital signal analysis algorithms are unable to deal with a short duration signal of this type, however, it is hoped that techniques being developed in Canada will enable more information to be deduced from the end of the recording.

In the aftermath of the Air India Boeing 747 accident (AI 182) in the North Atlantic on 23 June 1985 the Royal Armaments Research and Development Establishment (RARDE) were asked informally by AAIB to examine means of differentiating, by recording violent cabin pressure pulses, between the detonation of an explosive device within the cabin (positive pulse) and a catastrophic structural failure (negative pulse). Following the Lockerbie disaster it was considered that this work should be raised to a formal research project. Therefore, in February 1989, it was recommended that the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems.

Preliminary results from these trials indicates that if a suitable sensor can be developed its output will need to be recorded in real time and therefore it may require wiring into the CVR installation. This will further strengthen the requirement for battery back up of the CVR electrical power supply.

4. Flight recorder electrical system

4.1 CVR/DFDR electrical wiring.

The flight recorders were located in the left rear fuselage just forward of the rear pressure bulkhead. Audio information to the CVR ran along the left hand side of the aircraft, at stringer 11. Electrical power to the CVR followed a similar route on the right hand side of the aircraft crossing to the left side above the rear passenger toilets. DFDR electrical power and signal information

followed the same route as the CVR audio information.

4.2 Flight recorder power supply

The DFDR, CVR and the transponders were all powered from the essential alternating current (AC) bus. This bus was capable of being powered by any generator, however, in normal operation the selector switch on the flight engineers panel is selected to "normal" connecting the essential bus to number 4 generator. When the cockpit of Flight PA103 was examined the selector switch was found in the normal position.

4.3 Aircraft alternating current power supplies

AC electrical power to the aircraft was provided by 4 engine driven generators, see Figure C-13. Each generator was driven at constant speed through a constant speed drive (CSD) and connected to a separate bus-bar through a generator control breaker (GCB). The 4 generators were connected to a parallel bus-bar (sync bus) by individual bus tie breakers (BTBs). Control and monitoring of the AC electrical system was achieved through the flight engineer's instrument panel. In normal operation the generators operated in parallel, i.e with the BTBs closed.

4.4 Fault conditions

Analysis of the CVR CAM channel signal indicated that approximately 60 milliseconds after the sound on the CAM channel an electrical transient was recorded on all 4 channels and that approximately 110 milliseconds later the CVR had ceased recording. Within the accuracy of the available timing information it is believed that the incoming VHF was lost at the same time, indicating an AC power supply fault.

The AC electrical system was protected from faults in individual systems or equipment by fuses or circuit breakers. Faults in the generators or in the distribution bus-bars and feeders were dealt with automatically by opening of the GCBs and opening or closing of the BTBs. In the event of fault conditions causing the disconnection of all 4 generators electrical power for essential services, including VHF radio, was provided by a battery located in the cockpit.

The short time interval of 55 milliseconds after which the AC supply to the flight recorders was lost limits the basis on which a fault path analysis of the AC electrical system can be undertaken. On the available information only a differential (feeder) fault could have isolated the bus-bar this quickly, with the generator field control relay taking 20 milliseconds to trip. However, in normal operation, the generators would have been operating in parallel and the essential AC bus-bar would have been supplied via the number 4 BTB from the sync bus. If the fault conditions had continued, a further 40 to 100 milliseconds would have elapsed before the BTB opened. If the BTB was open prior to the fault it would have attempted to close and restore the supply to the essential bus. Any automatic switching causes electrical transients to appear on the CVR and data losses on the FDR. Both the CVR and the FDR indicate that a clean break of the AC supply occurred with no electrical transients associated with BTBs open or closing in an attempt to restore power. In the absence of any additional information only two possibilities are apparent:

i) That all 4 generators were simultaneously affected causing a total loss of AC electrical power. The feeders for the left and right side generators run on opposite sides of the aircraft under the passenger cabin floor. The only situation envisaged that could cause simultaneous loss of all 4 generators is the disruption of the passenger cabin floor across its entire width.

ii) That disruption of the main equipment centre, housing the control units for the AC electrical system, caused the loss of all AC power. However, again it would have to affect both the left and right sides of the aircraft as the control equipment is located at left and right extremes of the main equipment centre.

The nature of the event may also produce effects that are not understood. It is also to be noted that a sudden loss of electrical power to the flight recorders has been reported in other B747 accidents, e.g. Air India, AI 182.

5. Seismic data

The British Geological Survey has a number of seismic monitoring stations in Southern Scotland. Stations close to Lockerbie recorded a seismic event caused by the wing section crashing on Lockerbie. The seismic monitors are time correlated with the British Telecom Rugby standard. Using this and calculating the time for the various waves to reach the recording stations it was possible for the British Geological Survey to conclude that the event occurred at 19.03:36.5 hrs \pm 1 second.

Attempts were made to correlate various smaller seismic events with other wreckage impacts. However, this was not conclusive because the nearest recording station was above ground and due to the high winds at the time of the accident had considerable noise on the trace. In addition, little of the other wreckage had the mass or impact velocity to stimulate the sensors.

6. Time correlation

6.1 Introduction

The sources of each time encoded recording were asked to provide details of their time standard and any known errors in the timings on their recordings. Although the resolution of the recorded time sources is high it was not possible to attach an accuracy of better than ± 1 second due to possible errors in synchronising the recorded time with the associated standard. The following time sources were available and used in determining the significant events in the investigation:-

i) ATC

ATC communications were recorded along with a time signal. The time source for the ATC tape was the British Telecom "Tim" signal. Any error in setting the time when individual tapes are mounted was logged.

ii) Recorded radar data

A time signal derived from the British Telecom "Rugby" standard was included on radar recordings. The Rugby and Tim times were assumed to be of equal accuracy for timing purposes.

iii) The DFDR had UTC recorded.

The source of this time was the flight engineer's clock. This clock was set manually and therefore this time was subject to a significant fixed error as well any inaccuracy in the clock.

iv) The CVR had no time signal.

However, the CVR was correlated with the ATC time through the RTF and with the DFDR, by correlating the press to talk events on the FDR with the press to talk signature on the CVR.

v) Seismic recordings

Seismic recordings included a timing signal derived from the British Telecom Rugby standard.

6.2 Analysis and correlation of times

The Scottish and Shanwick ATC tapes were matched with each other and with the CVR tape. The CVR recording speed was adjusted by peaking its recorded 400 Hz AC power source frequency. This correlation served as a double check on any fixed errors on the ATC recordings and to fix events on the CVR to UTC. The timing of the sound on the CAM channel of the CVR was made simpler because Shanwick was transmitting when it occurred. From this it was possible to determine that the sound on the CVR occurred at 19.02:50 hrs ± 1 second.

With the CVR now tied to the Tim standard it was possible to match the RTF keying on the CVR with the RTF keying events on the FDR. These events on the FDR were sampled and recorded once per second, it was therefore possible for a 1 second delay to be present on the FDR. This potential error was reduced by obtaining the best fit between a number of RTF keyings and a time correlation between the FDR and CVR of ± 1 second was achieved. From this it was determined, within this accuracy, that electrical power was removed from the CVR and FDR at the same time.

From the recorded radar data it was possible to determine that the last recorded SSR return was at 19.02:46.9 hrs and that by the next rotation of the radar head a number of primary returns, some left and right of track, were evident. Time intervals between successive rotations of the radar head became more difficult to use as the head painted more primary returns.

The point at which aircraft wreckage impacted Lockerbie was determined using the time recorded by seismic activity detectors. A seismic event measuring 1.6 on the Richter scale was detected and, with appropriate time corrections for times of the waves to reach the sensors, it was established that this occurred at 19.03:36.5 hrs ± 1 second. A further check was made by triangulation techniques from the information recorded by the various sensors.

7. Recorded radar information

7.1 Introduction

Recorded radar information on the aircraft was available from from 4 radar sites. Initial analysis consisted of viewing the recorded information as it was shown to the controller on the radar screen, from this it was clear that the flight had progressed in a normal manner until Secondary Surveillance Radar (SSR) was lost. There was a single primary return received by both Great Dun Fell and Claxby radars approximately 16 seconds before SSR returns were lost. The Lowther Hill and St. Annes radars did not see this return. The Great Dun Fell radar recording was watched for 1 hour both before and after this single return for any signs of other spurious returns, but none was seen. The return was only present for one paint and no explanation can be offered for its presence.

7.2 Limitations of recorded radar data

Before evaluating the recorded radar data it is important to highlight limitations in radar performance that must be taken into account when interpreting primary radar data. The radar

system used for both primary and secondary radar utilised a rotating radar transmitter/receiver (Head). This means that a return was only visible whilst the radar head was pointing at the target, commonly called painting or illuminating the target. In the case of this accident the rotational speeds of the radar heads varied from approximately 10 seconds for the Lowther Hill Radar to 8 Seconds for the Great Dun Fell Radar.

Whilst it was possible to obtain accurate positional information within a resolution of 0.09° of bearing and $\pm 1/16$ nautical mile range for an aircraft from SSR, incorporating mode C height encoding, primary radar provided only slant range and bearing and therefore positional information with respect to the ground was not accurate.

The structural break-up of an aircraft releases many items which were excellent radar reflectors eg. aluminium cladding, luggage containers, sections of skin and aircraft structure. These and other debris with reflective properties produce "clutter" on the radar by confusing the radar electronics in a manner similar to chaff ejected by military aircraft to avoid radar detection.

Even when the target is not masked by clutter repetitive detection of individual targets may not be possible because detection is a function of the target effective area which, for wreckage with its irregular shape, is not constant but fluctuates wildly. These factors make it impossible to follow individual returns through successive sweeps of the radar head.

7.3 Analysis of the radar data

The detailed analysis of the radar information concentrated on the break-up of the aircraft. The Royal Signals and Radar Establishment (RSRE) corrected the radar returns for fixed errors and converted the SSR returns to latitude and longitude so that an accurate time and position for the aircraft could be determined. This information was correlated with the CVR and ATC times to establish a time and position for the aircraft at the initial disintegration.

For the purposes of this analysis the data from Great Dun Fell Radar has been presented. Figures C-14 to C-23 show a mosaic picture of the radar data i.e. each figure contains the information on the preceding figure together with more recently recorded information. Figure C-14 shows the radar returns from an aircraft tracking 321° (Grid) with a calculated ground speed of 434 kts. Reading along track (towards the top left of Figure C-14) there are 6 SSR returns with the sixth and final SSR return shown decoded: squawk code 0357 (identifying the aircraft as N739PA); mode C indicating FL310; and the time in seconds (68566.9 seconds from 00:00, i.e. 19.02:46.9 hrs).

At the next radar return there is no SSR data, only 4 primary returns. One return is along track close to the expected position of the aircraft if it had continued at its previous speed and heading. There are 2 returns to the left of track and 1 to the right of track. Remembering the point made earlier about clutter, it is unlikely that each of these returns are real targets. It can, however, be concluded that the aircraft is no longer a single return and, considering the approximately 1 nautical mile spread of returns across track, that items have been ejected at high speed probably to both right and left of the aircraft. Figure C-15 shows the situation after the next head rotation. There is still a return along track but it has either slowed down or the slant range has decreased due to a loss of altitude.

Each rotation of the radar head thereafter shows the number of returns increasing with those first identified across track in Figure C-14 having slowed down very quickly and followed a track along the prevailing wind line. Figure C-20 shows clearly that there has been a further break-up of the

aircraft and subsequent plots show a rapidly increasing number of returns, some following the wind direction and forming a wreckage trail parallel to and north of the original break-up debris. Additionally it is possible that there was some break-up between these points with a short trail being formed between the north and south trails. From the absence of any returns travelling along track it can be concluded that the main wreckage was travelling almost vertically downwards for much of the time.

The geographical position of the final secondary return at 19.02:46.9 hrs was calculated by RSRE to be OS Grid Reference 15257772, annotated Point A in Appendix B, Figure B-4, with an accuracy considered to be better than ± 300 metres. This return was received 3.1 ± 1 seconds before the loud sound was recorded on the CVR at 19.02:50 hrs. By projecting from this position along the track of 321° (Grid) for 3.1 ± 1 seconds at the groundspeed of 434 kts, the position of the aircraft was calculated to be OS Grid Reference 14827826, annotated Point B in Appendix B, Figure B-4, within an accuracy of ± 525 metres. Based on the evidence of recorded data only, Point B therefore represents the geographical position of the aircraft at the moment the loud sound was recorded on the CVR.

8. Conclusions

The almost instant destruction of Flight PA103 resulted in no direct evidence on the cause of the accident being preserved on the DFDR. The CVR CAM track contained a loud sound 170 milliseconds before recording ceased. Sixty milliseconds of this sound were while power was applied to the recorder; after this period the amplitude decreased. It cannot be determined whether the decrease was because of reducing recorder drive or if the sound itself decreased in amplitude. Analysis of both flight recorders shows that they stopped because the electrical supply was removed and that there were valid signals available to both recorders at that time.

The most important contribution to the investigation that the flight recorders could make was to pinpoint the time and position of the event. As the timescale involved was so small in relation to the resolution and accuracy of many of the recorded time sources it was necessary to analyse collectively all the available recordings. From the analysis of the CVR, DFDR, ATC tapes, radar data and the seismic records it was concluded that the loud sound on the CVR occurred at 19.02:50 hrs ± 1 second and wreckage from the aircraft crashed on Lockerbie at 19.03:36.5 hrs ± 1 second, giving a time interval of 46.5 ± 2 seconds between these two events. When the loud sound was recorded on the CVR, the geographical position of the aircraft, based on the evidence of recorded data, was calculated to be within 525 metres of OS Grid Reference 14827826.

Eight seconds after the sound on the CVR the Great Dun Fell radar showed 4 primary radar returns. The returns indicated a spread of wreckage in the order of 1 nautical mile across track. On successive returns of the radar, two parallel wreckage trails are seen to develop with the second trail, to the north, becoming evident 30 to 40 seconds after the first.

APPENDIX D

CRITICAL CRACK CALCULATIONS

It was assumed that the fuselage rupture and associated star-burst petalling process was driven by an expanding 'bubble' of high pressure gas, produced by the conversion of solid explosive material into gas products. As the explosive gas pressures reduced due to dissipation through the structure and external venting, the service differential pressure loading would have taken over from the explosive pressures as the principal force driving the skin fractures.

The high temperature gas would initially have been confined within the container where, because of the low volume, the pressure would have been extremely high (too high for containment) and the gas bubble would have expanded violently into the cavities of the fuselage between the outer skin and the container. This gas bubble would have continued to expand, with an accompanying fall in pressure due to the increasing volume combined with a corresponding drop in temperature.

The precise nature of the gas expansion process could not be determined directly from the evidence and it was therefore necessary to make a number of assumptions about its behaviour, based on the geometry of the hull and the area of fuselage skin which the high pressure bubble would have ruptured. Essentially, it was assumed that the gas bubble would expand freely in the circumferential direction, into the cavity between the fuselage skin and the container. In contrast, the freedom for the bubble to expand longitudinally would have been restricted by the presence of the fuselage frames, which would have partially blocked the passage of gas in the fore and aft directions. However, the pressures acting on the frames would have been such that they would have buckled and failed, allowing the gas to vent into the next 'bay', producing failure of the next frame. This sequential frame-failure process would have continued until the pressure had fallen to a level which the frames could withstand. During the period of frame failure and the associated longitudinal expansion of the gas bubble, this expansion rate was assumed to be half that of the circumferential rate.

It was assumed that venting would have taken place through the ruptured skin and that the boundary of the petalled hole followed behind the expanding gas bubble, just inside its outer boundary, i.e. the expanding gas bubble would have stretched and 'unzipped' the skins as it expanded. This process would have continued until the gas bubble had expanded/vented to a level where the pressure was no longer able to drive the petalling mechanism because the skin stresses had reduced to below the natural strength of the material.

The following structural model was assumed:

- (i) The pressurised hull was considered to be a cylinder of radius 128 inches, divided into regular lengths by stiff frames.
- (ii) The contributions of the stringers and frames beyond the petalled region were considered to be the equivalent of a reduction of stress in the skins by 20%, corresponding to an increase in skin thickness from 0.064 inches to 0.080 inches.
- (iii) Standing skin loads were assumed to be present due to the service differential pressure, i.e.. it was assumed that no significant venting of internal cabin pressure occurred within the relevant timescale.
- (iv) The mechanism of bubble pressure load transfer into the skins was:
 - a) Hoop direction -conventional membrane reaction into hoop stresses
 - b) Longitudinal direction - reaction of pressures locally by the frames, restrained by the skins.

The critical crack calculations were based upon the generalised model of a plate under biaxial loading in which there was an elliptical hole with sharp cracks emanating from it. This is a good approximation of the initial condition, i.e. the shattered hole, and an adequate representation of the subsequent phase, when the hole was enlarging in its star-burst, petalling, mode.

The analyses of critical crack dimensions in the circumferential and longitudinal directions were based on established Fracture Resistance techniques. The method utilises fracture resistance data for the material in question to establish the critical condition at which the rate of energy released by the crack just balances the rate of energy absorbed by the material in the cracking process, i.e. the instantaneous value of the parameter K_r , commonly referred to as the fracture toughness K_c . From this, the relationship between critical stress and crack length can be determined.

Using conventional Linear Elastic Fracture Mechanics (LEFM) with fracture toughness data from RAE experimental work and published geometric factors relating to cracks emanating from elliptical holes, the stress levels required to drive cracks of increasing lengths in both circumferential and longitudinal directions were calculated. The skin stresses at sequential stages of the expanding gas bubble/skin petalling process were then calculated and compared with these data.

The results of the analysis indicated that, once the large petalled hole had been produced by explosive gas overpressure, the hoop stresses generated by fuselage pressurisation loads acting alone would have been sufficient to drive cracks longitudinally for large distances beyond the boundaries of the petalled hole. Thus, with residual gas overpressure acting as well, the 43 feet (total length) longitudinal fractures observed in the wreckage are entirely understandable. The calculations also suggested that the hoop fractures, due to longitudinal stresses in the skins, would have extended beyond the boundary of the petalled hole, though the excess stress driving the fractures in this direction would have been much smaller than for the longitudinal fractures, and the level of uncertainty was greater due to the difficulty of producing an accurate model reflecting the diffusion of longitudinal loads into the skins. Nevertheless, the results suggested that the circumferential cracks would extend downwards just beyond the keel, and upwards as far as the window belt - conclusions which accord reasonably well with the wreckage evidence.

APPENDIX E

POTENTIAL REMEDIAL MEASURES

1. Introduction

In the following discussion, those damage mechanisms which appear to have contributed to the catastrophic structural failure of Flight PA103 are identified and possible ways of reducing their damaging effects are suggested. These suggestions are intended to stimulate thought and discussion by manufacturers, airworthiness authorities, and others having an interest in finding solutions to the problem; they are intended to serve as a catalyst rather than to lay claim to a definitive solution. On the basis of the Flight PA103 investigation, damage is likely to fall into two categories: direct explosive damage, and indirect explosive damage.

2. Direct explosive damage

The most serious aspect of the direct explosive damage on the structure is the large, jagged aperture

in the pressure hull, combined with frame and stringer break-up, which results from the star-burst rupture of the fuselage skin. Because of its uncontrolled size and position, and the naturally radiating cracks which form as part of the petalling process, the skin's critical crack length (under pressurisation loading) is likely to be exceeded, resulting in unstable crack propagation away from the boundary of the aperture. Such cracks can lead to a critical loss of structural integrity at a time when additional loads are likely to be imposed on the structure due to reflected blast pressure and/or aircraft aerodynamic and inertial loading.

A further complicating factor is that the size of this aperture is likely to be sufficiently large to allow complete cargo containers and other debris to be ejected into the airstream, with a high probability of causing catastrophic structural damage to the empennage.

3. Indirect explosive damage

Indirect explosive damage (channelling or ducting of explosive energy in the form of both shock waves and supersonic gas flows) is likely to occur because of the network of interlinked cavities which exist, in various forms, in all large commercial aircraft, particularly below cabin floor level. This channeling mechanism can produce critical damage at significant distances from the source of the explosion.

In addition to the structural damage, aircraft flight control and other critical systems will potentially be disrupted, both by the explosive forces and as a result of structural break-up and distortions. The discussion which follows focuses on possible means of limiting structural damage of the kind which occurred on Flight PA103. Undoubtedly, such measures will also have beneficial effects in limiting systems damage. However, system vulnerability can further be reduced by applying, wherever possible, those techniques used on military aircraft to reduce vulnerability to battle damage; multiplexed, multiply redundant systems using distributed hardware to minimise risk of a single area of damage producing major system disruption. Fly by wire flight control systems potentially offer considerable scope to achieve these goals, but the same distributed approach would also be required for the electronic and other equipment which, in current aircraft, tends to be concentrated into a small number of 'equipment centres'.

4. Remedial measures to reduce structural damage

Whilst pure containment of the explosive energy is theoretically possible, in an aviation context such a scheme would not be viable. Any unsuccessful attempt to contain the explosive will probably produce greater devastation than the original (uncontained) explosion since all the explosive energy would merely be stored until the containment finally ruptured, when the stored energy would be released together with massive fragmentation of the containment.

However, a mixed approach involving a combination of containment, venting, and energy absorption should provide useful gains provided that a systematic rather than piecemeal approach is adopted, and that the scheme also addresses blast channelling. The following scheme is put forward for discussion, primarily as means of identifying, by example, how the various elements of the problem might be approached at a conceptual level and to provide a stimulus for debate. No detailed engineering solutions are offered, but it is firmly believed that the requirements of such a scheme could be met from a technical standpoint. The proposed scheme is based on the need to counter a threat similar to that involving Flight PA103, i.e. a high explosive device placed within a baggage container, however, the principles should be applicable to other aircraft types.

Such a scheme might comprise several 'layers' of defence. The first two layers, one within the

other, are essentially identical and provide partial containment of the explosive energy and the redirection of blast out from the compartment via pre-determined vent paths. Although the containment is temporary, it must provide an effective barrier to uncontrolled venting, preventing the escape of blast except via the pre-designated paths.

The third layer comprises a pre-determined area of fuselage skin, adjoining the outer end of the vent path, designed to rupture or burst in a controlled manner, providing a large vent aperture which will not tend to crack or rupture beyond the designated boundaries.

A fourth layer of protection has two elements, both intended to limit the propagation of shock waves through the internal cavities in the hull. The first element comprises the closure of any gaps between the vent apertures in the two innermost containment layers and the vent aperture in the outer skin. This effectively provides an exhaust duct connecting the inner and outer vent apertures to minimise leakage into the intervening structure and cavities around the cargo hold. The second element comprises the incorporation of an energy absorbing lining material within all the cavities in the lower hull, to absorb shock energy, limit shock reflection and limit the propagation of pressure waves which might enter the cavities, for example because of containment layer breakthrough.

5 Possible application to Boeing 747 type aircraft

5.1 Container Modification

The obvious candidates for the inner containment layer are the baggage containers themselves. Existing containers are of crude construction, typically comprising aluminium sheet sides and top attached to an aluminium frame with a fabric reinforced access curtain, or have sides and top of fibreglass laminate attached to a robust aluminium base section.

These containers are stacked in the aircraft in such a manner that on three sides (except for the endmost containers) the baggage within the adjoining containers provides an already highly effective energy absorbing barrier. If the container is modified so that loading access is via the outboard side of the container rather than at the end, i.e. the curtain is put on the faces shown in Figure E-1, then only the top and base are 'unbacked' by other containers, leaving the outboard face as a vent region.

The proposal is therefore that a modified container is developed in which the access is changed from the end to the outside face only, and which is modified to improve the resistance to internal pressures and thus encourage venting via the new access curtain only. How the container is actually modified to achieve the containment requirement is a matter of detail design, but two approaches suggest themselves, both involving the use of composite type materials. The first approach is to adopt a scheme for a rigid container which relies on a combination of energy absorption and burst strength to prevent uncontrolled breakout of explosive energy. The second approach is to use a 'flexible' container, i.e. rigid enough for normal use, but sufficiently flexible to allow gross deformation of shape without rupture. This, particularly if used with a backing blanket made from high performance material to resist fragmentation, could deform sufficiently to allow the container to bear against, and partially crush, adjoining containers. In this way, the shock energy transmission should be significantly reduced and the inherent energy absorption capability and mass of the baggage in adjoining containers could be utilised, whilst still retaining the high pressure gas for long enough to allow venting via the side face. Clearly, care would need to be taken to ensure that the container vent aperture remained as undistorted as possible, to ensure minimal leakage at the interface.

5.2 Cargo bay liner

The existing cargo bay liner is a thin fibreglass laminate which lines the roof and sidewalls of the cargo hold. There is no floor as such; instead, the containers are supported on rails running fore and aft on the tops of the fuselage frame lower segments. In a number of areas, there are zipped fabric panels let into the liner to provide access to equipment located behind. The liner 'ceiling' is suspended on plastic pillars approximately 2 centimeters below the bottom of the main cabin floor beams. The purpose of the liner is solely to act as a general barrier to protect wiring looms and systems components.

The proposal is to produce a new liner designed to provide the second level of containment, essentially at 'floor' and 'roof' level only [Figure E-1]. The dimensional constraints are such that potentially quite thick material could be incorporated (leaving aside the weight problem), permitting not only a rigid liner design, but semi-rigid or flexible linings backed by energy absorbing blanket materials.

The liner would be designed to provide an additional barrier at the base and roof of the containers, which unlike the sides, are not protected by adjoining containers. The outside ends of these barrier elements must effectively seal against the vent apertures in the containers, to minimise leakage into the fuselage cavities.

5.3 Structural blow-out regions.

The final element in the containment/venting part of the scheme is a line of blow-out regions in the fuselage skins, coinciding exactly with the positions of the vent apertures in the cargo containers and cargo bay liner. These should extend along the length of the cargo hold, zoned in such a way that rupture due to rapid overpressure will occur in a controlled manner. The primary function of the blow-out regions would be to provide immediate pressure relief by allowing the inevitable skin rupture to take place only within pre-determined zones, limiting the extent of the skin tearing by means of careful stiffness control at the boundary of the blow-out regions.

The structural requirements of such panels are perhaps the most difficult challenge to meet, particularly for existing designs. However, it is believed that by giving appropriate consideration to the directionality of fastening strengths, and the use of external tear straps, it should be possible to design the structure to carry the normal service loads whilst creating a pre-disposition to rupturing in a controlled manner in response to gross pressure impulse loading.

The implementation of such features will need carefully balanced design in order to provide local stiffening, sufficient to control and direct the tear processes, without creating stiffness discontinuities which could lead to fatigue problems during extended service. However, the degree of reinforcement needed at the blow-out aperture need only be sufficient to limit tearing and to sustain the aircraft long enough to complete the flight unpressurised.

All aircraft have pre-existing strength discontinuities, despite the efforts of the designers to eliminate them. By choosing the positions of butt joints, lap joints, anti-tear straps and similar structural features in future designs, so as to incorporate them into the boundary of the blow-out panel region, the natural "tear here" tendencies of such features could possibly be turned to advantage. In the case of current generation aircraft, the positions of existing lines of weakness at such features will determine the optimum position for structural blow-out areas, and hence the positions of the container and cargo bay liner blow-out panels. A limited amount of local structural reinforcement (e.g. in the form of external anti-tear straps), carried out as part of a modification

program, could perhaps fine tune the tearing properties of existing lines of weakness, potentially producing significant improvements.

5.4 Closure of cavities

There are four main classes of cavity which will need to be addressed on the Boeing 747, and most other modern aircraft. These are:

- (i) The channels formed between fuselage frames
- (ii) The cross-ship cavities between cabin floor beams
- (iii) Longitudinal 'manifold' cavities on each side of the cargo deck, running fore and aft in the space behind the upper sidewall areas of the cargo bay liner.
- (iv) Air conditioning vents along the bottom of the cabin side-liner panels, which connect the side cavities below cabin floor level with the main passenger cabin.

If the containment barriers (i.e. modified cargo containers and cargo hold liner) can be made to prevent blast breakthrough into these cavities directly, then the only area where transfer can occur is at the interface between the container/cargo hold liner vent apertures and the fuselage skins at the blow-out region. This short distance will need to be sealed in order to form a short 'exhaust duct' between the container vent aperture and the fuselage skin. Since the shock and general explosive pressure will act mainly along the vent-duct axis, the pressure loading on the vent duct walls should not be excessive.

5.5 Attenuation of shock waves in structural cavities

To prevent the 'ducting' of any blast which does enter the fuselage cavities, either because of partial penetration of the containment barriers or leakage at the vent duct interfaces, the scheme requires the provision of lightweight energy absorbing material within the cavities to limit reflection and propagation of pressure waves within the cavities, and radiation of shock waves into the cabin from the conditioning air vents. Materials such as vermiculite, which are of low density yet have excellent explosive energy absorption properties, may have application in this area, perhaps in lieu of the existing insulation material.

Since the existing cavities often serve as part of the air conditioning outflow circuit, some consideration will need to be given to finding an alternative route. However, the flow rates are small compared with the total cross-sectional flow potential of the cavities and this function could be served by separate air conditioning ducts, or perhaps by restricting access to one or two cavities only (thus limiting the risk), or by using some form of blast valve to close off the air conditioning vents. Similarly, the requirement to vent pressure from the cabin in the event of a cargo bay decompression would also need to be addressed.

APPENDIX F

BAGGAGE CONTAINER EXAMINATION, RECONSTRUCTION AND RELATIONSHIP TO THE AIRCRAFT STRUCTURE

1. Introduction

During the wreckage recovery operation it became apparent that some items, identified as parts of baggage containers, exhibited blast damage. It was confirmed by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE), after detailed physical and chemical examination, that these items showed conclusive evidence of a detonating high performance plastic explosive. It was therefore decided to segregate identifiable container parts and reconstruct any that showed evidence from the effect of Improvised Explosive Device (IED). It was evident, from the main wreckage layout that the IED had been located in the forward cargo hold and, although all baggage container wreckage was examined, only items from the forward hold showing the relevant characteristics were considered for the reconstruction. This Appendix documents the reconstruction of two particular containers and, from their position within the forward fuselage, defines the location of the IED.

2 Container Arrangement

Information supplied by Pan Am showed that this aircraft had been loaded with 12 baggage containers and two cargo pallets in the forward hold located as shown in Figure F-1. Three containers were recorded as being of the glass fibre reinforced plastic type (those at positions 11L, 13L and 21L) with the remaining 9 being of metal construction.

3. Container Description

All the baggage containers installed in the forward cargo hold were of the LD3 type (lower deck container, half width - cargo) and designated with the codes AVE, for those constructed from aluminum alloy, and AVA or AVN for those constructed from fibreglass. Each container was specifically identified with a four digit serial number followed by the letters PA and this nine digit identifier was present at the top of three sides of each container in black letters/numbers approximately 5 inches tall. Detail drawings and photographs of a typical metal container are shown in Figure F-2. Each container was essentially a 5 feet cube with a 17 inch extension over its full length to the left of the access aperture. In order to fit within the section of the lower fuselage this extension had a sloping face at its base joining the edge of the container floor to the left vertical sidewall at a position some 20 inches above the floor. The access aperture on the AVE type container was covered by a blue reinforced plastic curtain, fixed to the container at its top edge, braced by two wires and central and lower edge cross bars which engaged with the aperture structure. The strength of this type of container superstructure was provided by the various extruded section edge members, attached to a robust floor panel, with a thin aluminum skin providing baggage containment and weatherproofing.

4. Container Identification

Discrimination between forward and rear cargo hold containers was relatively straightforward as the rear cargo hold wreckage was almost entirely confined to the town of Lockerbie and was characteristically different from that from the forward hold, in that it was generally severely crushed and covered in mud. The forward hold debris, by comparison, was mostly recovered from the southern wreckage trail some distance from Lockerbie and had mainly been torn into relatively large sections.

All immediately identifiable parts of the forward cargo containers were segregated into areas designated by their serial numbers and items not identified at that stage were collected into piles of

similar parts for later assessment. As a result of this two containers, one metal and one fibreglass, were identified as exhibiting damage likely to have been caused by the IED. From the Pan Am records the metal container of these two had been positioned at position 14L, and the fibreglass at position 21L (adjacent positions, 4th and 5th from the front of the forward cargo hold on the left side). The serial numbers of these containers were respectively AVE 4041 PA and AVN 7511 PA.

5. Container Reconstruction

Those parts which could be positively identified as being from containers AVE 4041 PA and AVN 7511 PA were assembled onto one of three wooden frameworks; one each for the floor and superstructure of container 4041, and one for the superstructure of container 7511. Figures F-3 to F-9 show the reconstruction of container 4041 and Figure F-10 shows the reconstructed forward face of container 7511. Approximately 85% of container 4041 was identified, the main missing sections being the aft half of the sloping face skin and all of the curtain. Two items were included which could not be fracture or tear matched to container 4041, however, they showed the particular type of blast damage exhibited only by items from this container.

While this work was in progress a buckled section of skin from container 4041 was found by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device.

Examination of all other component parts of the remaining containers from the front and rear cargo holds did not reveal any evidence of blast damage similar to that found on containers 4041 and 7511.

6. Wreckage Distribution

Those items which were positively identified as parts of container 4041 or 7511, and for which a grid reference was available, were found to have fallen close to the southern edge of the southern wreckage trail. This indicated that one of the very early events in the aircraft break-up sequence was the blast damage to, and ejection of, parts of these two containers.

7. Fuselage Reconstruction

In order to gain a better understanding of the failure sequence, that part of the aircraft's fuselage encompassing the forward cargo hold was reconstructed at AAIB Farnborough. After all available blast damaged pieces of structure had been added, the floor of container 4041 was installed as near to its original position as the deformation of the wreckage would allow and this is shown in Figure F-11. The presence of this floor panel in the fuselage greatly assisted the three-dimensional assessment of the IED location. Witness marks between this floor and the aircraft structure, tie down rail, roller rail and relative areas of blast damage left no doubt that container 4041 had been located at position 14L at the time of detonation.

8. Analysis

The general character of damage that could be seen on the reconstructions of containers 4041 and 7511 was not of a type seen on the wreckage of any of the other containers examined. In particular, the reconstruction of the floor of container 4041 revealed an area of severe distortion, tearing and blackening localised in its aft outboard quarter which, together with the results of the

forensic examination of items from this part of the container, left no doubt that the IED had detonated within this container.

Within container 4041 the lack of direct blast damage (of the type seen on the outboard floor edge member and lower portions of the aft face structural members) on most of the floor panel in the heavily distorted area suggested that this had been protected by, presumably, a piece of luggage. The downward heaving of the floor in this area was sufficient to stretch the floor material, far enough to be cut by cargo bay sub structure, and distort the adjacent fuselage frames. This supported the view that the item of baggage containing the IED had been positioned fairly close to the floor but not actually placed upon it. The installation of the floor of container 4041 into the fuselage reconstruction (Figure F-11) showed the blast to have been centered almost directly above frame 700 and that its main effects had not only been directed mostly downwards and outboard but also rearwards. The blast effects on the aircraft skin were onto stringer 39L but centered at station 710 (Figure F-12). Downwards crushing at the top, and rearwards distortion of frame 700 was apparent as well as rearwards distortion of frame 720.

With the two container reconstructions placed together it became apparent that a relatively mild blast had exited container 4041 through the rear lower face to the left of the curtain and impinged at an angle on the forward face of container 7511. This had punched a hole, Figure F-10, approximately 8 inches square some 10 inches up from its base and removed the surface of this face inboard from the hole for some 50 inches. Radiating out from the hole were areas of sooting, and other black deposits, extending to the top of the container. No signs were present of any similar damage on other external or internal faces of container 7511 or the immediately adjacent containers 14R and 21R.

The above assessment of the directions of distortion, comparison of damage to both containers, and the related airframe damage adjacent to the container position, enabled the most probable lateral and vertical location of the IED to be established as shown in Figure F-13, centered longitudinally on station 700.

9. Conclusions

Throughout the general examination of the aircraft wreckage, direct evidence of blast damage was exhibited on the airframe only in the area bounded, approximately, by stations 700 and 720 and stringers 38L and 40L. Blast damage was found only on pieces of containers 4042 and 7511, the relative location and character of which left no doubt that it was directly associated with airframe damage. Thus, these two containers had been loaded in positions 14L and 21L as recorded on the Pan Am cargo loading documents. There was also no doubt that the IED had been located within container 14L, specifically in its aft outboard quarter as indicated in Figure F-13, centered on station 700.

Blast damage to the forward face of container 7511 was as a direct result of hot gases/fragments escaping from the aft face of container 4041. No evidence was seen to suggest that more than one IED had detonated on Flight PA103.

APPENDIX G

MACH STEM SHOCK WAVE EFFECTS

1. Introduction

An explosive detonation within a fuselage, in reasonably close proximity to the skin, will produce a high intensity shock wave which will propagate outwards from the centre of detonation. On reaching the inner surface of the fuselage skin, energy will partially be absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of the remaining energy will be transmitted, as a shock wave, through the skin and into the atmosphere but a significant amount of energy will be returned as a reflected shock wave, which will travel back into the fuselage interior where it will interact with the incident shock to produce Mach stem shocks - re-combination shock waves which can have pressures and velocities of propagation greater than the incident shock.

The Mach stem phenomenon is significant for two reasons. Firstly, it gives rise (for relatively small charge sizes) to a geometric limitation on the area of skin material which the incident shock wave can shatter. This geometric limitation occurs irrespective of charge size (within the range of charge sizes considered realistic for the Flight PA103 scenario), and thus provides a means of calculating the standoff distance of the explosive charge from the fuselage skin. Secondly, the Mach stem may have been a significant factor in transmitting explosive energy through the fuselage cavities, producing damage at a number of separate sites remote from the source of the explosion.

2. Mach stem shock wave formation

A Mach stem shock is formed by the interaction between the incident and reflected shock waves, resulting in a coalescing of the two waves to produce a new, single, shock wave. If an explosive charge is detonated in a free field at some standoff distance from a reflective surface, then the incident shock wave expands spherically until the wave front contacts the reflective surface, when that element of the wave surface will be reflected back (Figure G-1). The local angle between the spherical wave front and the reflecting surface is zero at the point where the reflecting surface intersects the normal axis, resulting in wave reflection directly back towards the source and maximum reflected overpressure at the reflective surface. The angle between the wave front and the reflecting surface at other locations increases with distance from the normal axis, producing a corresponding increase in the oblique angle of reflection of the wave element, with a corresponding reduction in the reflected overpressure. (To a first order of approximation, explosive shock waves can be considered to follow similar reflection and refraction paths to light waves, ref: "Geometric Shock Initiation of Pyrotechnics and Explosives", R Weinheimer, McDonnell Douglas Aerospace Co.) Beyond some critical (conical) angle about the normal axis, typically around 40 degrees, the reflected and incident waves coalesce to form Mach stem shock waves which, effectively, bisect the angle between the incident and reflected waves, and thus travel approximately at right angles to the normal axis, i.e. parallel with the reflective surface (detail "A", figure G-1).

3. Estimation of charge standoff distance from the fuselage skin

Within the constraint of the likely charge size used on Flight PA103, calculations suggested that the initial Mach stem shock wave pressure close to the region of Mach stem formation (i.e. the shock wave face-on pressure, acting at right angles to the skin), was likely to be more than twice that of the incident shock wave, with a velocity of propagation perhaps 25% greater. However, the Mach stem out-of-plane pressure, i.e. the pressure felt by the reflecting surface where the Mach stem touches it, would have been relatively low and insufficient to shatter the skin material. Therefore, provided that the charge had sufficient energy to produce skin shatter within the conical central region where no Mach stems form, the size of the shattered region would be a function mainly of charge standoff distance, and charge weight would have had little influence. Consequently, it was possible to calculate the charge standoff distance required to produce a given size of shattered skin

from geometric considerations alone. On this basis, a charge standoff distance of approximately 25 to 27 inches would have resulted in a shattered region of some 18 to 20 inches in diameter, broadly comparable to the size of the shattered region evident on the three-dimensional wreckage reconstruction.

Whilst the analytical method makes no allowance for the effect of the IED casing, or any other baggage or container structure interposed between the charge and the fuselage skin, the presence of such a barrier would have tended to absorb energy rather than re-direct the transmitted shock wave; therefore its presence would have been more critical in terms of charge size than of position. Certainly, the standoff distance predicted by this method was strikingly similar to the figure of 25 inches derived independently from the container and fuselage reconstructions.

**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

Appendix M: NTSB 92/02 United Airlines Flight 811

DOT National Transportation Safety Board National Transportation Safety Board
Washington, D.C. 20594

Brief of Accident

Adopted 06/25/1990

DCA89MA027

FILE NO. 63 02/24/89 HONOLULU, HI AIRCRAFT REG. NO. N4713U
TIME (LOCAL) - 02:09 HST

MAKE/MODEL - BOEING 747-122 AIRCRAFT DAMAGE - Substantial FATAL
SERIOUS MINOR/NONE

ENGINE MAKE/MODEL - P&W JT9D-3A CREW 0 3 16

NUMBER OF ENGINES - 4 PASS 9 2 326

OPERATING CERTIFICATES - Flag carrier/domestic

NAME OF CARRIER - UNITED AIRLINES

TYPE OF FLIGHT OPERATION - Scheduled

- International

- Passenger

REGULATION FLIGHT CONDUCTED UNDER - 14 CFR 121

LAST DEPARTURE POINT - HONOLULU, HI CONDITION OF LIGHT - Night (dark)

DESTINATION - AUCKLAND, OF

WEATHER INFO SOURCE- Pilot

AIRPORT PROXIMITY - Off airport/airstrip

AIRPORT NAME - Unk/Nr BASIC WEATHER - Visual (VMC)

RUNWAY IDENTIFICATION - Unk/Nr LOWEST CEILING - Unk/Nr

RUNWAY LENGTH/WIDTH (Feet) - Unk/Nr VISIBILITY - Unk/Nr

RUNWAY SURFACE - Unk/Nr WIND DIR/SPEED - Unk/Nr

RUNWAY SURFACE CONDITION - Unk/Nr TEMPERATURE (F) - 0

PRECIPITATION - Unk/Nr

PILOT-IN-COMMAND AGE - 59 FLIGHT TIME (Hours)

CERTIFICATES/RATINGS TOTAL ALL AIRCRAFT - 28000

Airline transport LAST 90 DAYS - Unk/Nr

Single-engine land, Multi-engine land, Single-engine sea TOTAL MRKE/MODEL - 1650

Glider TOTAL INSTRUMENT TIME - Unk/Nr

INSTRUMENT RATINGS

Airplane

FTL #811 WAS A SCHEDULED PASSENGER FLIGHT FROM LOS ANGELES TO SYDNEY, AUSTRALIA, WITH STOPS IN HONOLULU (HNL), HI, AND AUCKLAND, NEW ZEALAND. THE FLT WAS UNEVENTFUL UNTIL AFTER DEPARTURE FROM HNL. WHILE CLIMBING FROM FL220 TO FL230 THE CREW HEARD A "THUMP" FOLLOWED

BY AN EXPLOSION. AN EXPLOSIVE DECOMPRESSION WAS EXPERIENCED AND THE #3 AND #4 ENGS WERE SHUTDOWN BECAUSE OF FOD. THE FLT RETURNED TO HNL AND PASSENGERS WERE EVACUATED. INSPECTION REVEALED THE FORWARD LOWER LOBE CARGO DOOR DEPARTED INFLT CAUSING EXTENSIVE DAMAGE TO THE FUSELAGE AND CABIN ADJACENT TO THE DOOR. NINE PASSENGERS WERE EJECTED AND LOST AT SEA. INVESTIGATION CENTERED AROUND DESIGN AND CERTIFICATION OF THE DOOR WHICH ALLOWED IT TO BE IMPROPERLY LATCHED, AND THE OPERATION AND MAINTENANCE TO ASSURE AIRWORTHINESS OF THE DOOR AND LATCHING MECHANISM. (SEE NTSB/AAR-90/01)

Brief of Accident (Continued)

DCA89MA027

FILE NO. 63 02/24/89 HONOLULU, HI AIRCRAFT REG. NO. N4713U

TIME (LOCAL) - 02:09 HST

Occurrence# 1 AIRFRAME/COMPONENT/SYSTEM FAILURE/MALFUNCTION

Phase of Operation CLIMB - TO CRUISE

Findings

1. - DOOR, CARGO/BAGGAGE - UNLATCHED
2. - DOOR, CARGO/BAGGAGE - SEPARATION
3. - MAINTENANCE, INSPECTION OF AIRCRAFT - IMPROPER - COMPANY MAINTENANCE PERSONNEL
4. - ACFT/EQUIP, INADEQUATE DESIGN - MANUFACTURER
5. - ACFT/EQUIP, INADEQUATE STANDARD/REQUIREMENT - FAA(ORGANIZATION)
6. - AIR COND/HEATING/PRESSURIZATION - DECOMPRESSION

The National Transportation Safety Board determines that the Probable Cause(s) of this Accident was: THE SUDDEN OPENING OF THE IMPROPERLY LATCHED FORWARD LOBE CARGO DOOR IN FLIGHT AND THE SUBSEQUENT EXPLOSIVE DECOMPRESSION. CONTRIBUTING TO THE ACCIDENT WAS A DEFICIENCY IN THE DESIGN OF THE CARGO DOOR LOCKING MECHANISMS, WHICH MADE THEM SUSCEPTIBLE TO INSERVICE DAMAGE, AND WHICH ALLOWED THE DOOR TO BE UNLATCHED, YET TO SHOW A PROPERLY LATCHED AND LOCKED POSITION. ALSO CONTRIBUTING TO THE ACCIDENT WAS THE LACK OF PROPER MAINTENANCE AND INSPECTION OF THE CARGO DOOR BY UNITED AIRLINES, AND A LACK OF TIMELY CORRECTIVE ACTIONS BY BOEING AND THE FAA FOLLOWING A PREVIOUS DOOR OPENING INCIDENT.

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NTSB/AAR-92/02

(SUPERSEDES NTSB/AAR-90/01)

NATIONAL

TRANSPORTATION

SAFETY

BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

EXPLOSIVE DECOMPRESSION--

LOSS OF CARGO DOOR IN FLIGHT

UNITED AIRLINES FLIGHT 811

BOEING 747-122, N4713U

HONOLULU, HAWAII

FEBRUARY 24, 1989

U.S. GOVERNMENT PRINTING OFFICE: 1989 0-942-365

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NATIONAL TRANSPORTATION

SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

EXPLOSIVE DECOMPRESSION-- LOSS OF CARGO DOOR IN FLIGHT UNITED AIRLINES
FLIGHT 811 BOEING 747-122, N4713U HONOLULU, HAWAII FEBRUARY 24, 1989

Adopted: March 18, 1992 Notation 5059C

Abstract: This report explains the explosive decompression resulting from the loss of a cargo door in flight on United Airlines flight 811, a Boeing 747-122, near Honolulu, Hawaii, on February 24, 1989. The safety issues discussed in the report are the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, and emergency response. Recommendations concerning these issues were made to the Federal Aviation Administration, the State of Hawaii, and the U.S. Department of Defense.

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EXECUTIVE SUMMARY

On February 24, 1989, United Airlines flight 811, a Boeing 747-122, experienced an explosive decompression as it was climbing between 22,000 and 23,000 feet after taking off from Honolulu, Hawaii, en route to Sydney, Australia with 3 flightcrew, 15 flight attendants, and 337 passengers aboard.

The airplane made a successful emergency landing at Honolulu and the occupants evacuated the airplane. Examination of the airplane revealed that the forward lower lobe cargo door had separated in flight and had caused extensive damage to the fuselage and cabin structure adjacent to the door. Nine of the passengers had been ejected from the airplane and lost at sea.

A year after the accident, the Safety Board was uncertain that the cargo door would be located and recovered from the Pacific Ocean. The Safety Board decided to proceed with a final report based on the available evidence without the benefit of an actual examination of the door mechanism. The original report was adopted by the Safety Board on April 16, 1990, as NTSB/AAR-90/01.

Subsequently, on July 22, 1990, a search and recovery operation was begun by the U.S. Navy with the cost shared by the Safety Board, the Federal Aviation Administration, Boeing Aircraft Company, and United Airlines. The search and recovery effort was supported by Navy radar data on the separated cargo door, underwater sonar equipment, and a manned submersible vehicle. The effort was successful, and the cargo door was recovered in two pieces from the ocean floor at a depth of 14,200 feet on September 26 and October 1, 1990.

Before the recovery of the cargo door, the Safety Board believed that the door locking mechanisms had sustained damage in service prior to the accident flight to the extent that the door could have been closed and appeared to have been locked, when in fact the door was not fully latched. This

belief was expressed in the report and was supported by the evidence available at the time. However, upon examination of the door, the damage to the locking mechanism did not support this hypothesis. Rather, the evidence indicated that the latch cams had been backdriven from the closed position into a nearly open position after the door had been closed and locked. The latch cams had been driven into the lock sectors that deformed so that they failed to prevent the back-driving.

Thus, as a result of the recovery and examination of the cargo door, the Safety Board's original analysis and probable cause have been modified. This report incorporates these changes and supersedes NTSB/AAR-90/01.

The issues in this investigation centered around the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, cabin safety, and emergency response.

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

As a result of this investigation, the Safety Board issued safety recommendations concerning cargo doors and other nonplug doors on pressurized transport category airplanes, cabin safety, and emergency response.

NATIONAL TRANSPORTATION SAFETY BOARD WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

EXPLOSIVE DECOMPRESSION-- LOSS OF CARGO DOOR IN FLIGHT UNITED AIRLINES
FLIGHT 811 BOEING 747-122, N4713U HONOLULU, HAWAII FEBRUARY 24, 1989

1. FACTUAL INFORMATION

1.1 History of the Flight

On February 24, 1989, United Airlines (UAL) flight 811, a Boeing 747-122 (B-747), N4713U, was being operated as a regularly scheduled flight from Los Angeles, California (LAX) to Sydney, Australia (SYD), with intermediate stops in Honolulu, Hawaii (HNL) and Auckland, New Zealand (AKL).

The flightcrew assigned to the LAX/HNL route segment reported no difficulty during their flight.

A flightcrew change occurred when flight 811 arrived at HNL. The oncoming captain stated that he and his crew reported to UAL operations 1 hour and 15 minutes prior to the flight's scheduled departure time from HNL. The crew had completed a 34-hour layover (rest period) in HNL.

The captain reviewed the flight plan, the weather, pertinent NOTAMs, and maintenance records, and signed the Instrument Flight Rules (IFR) clearance before boarding the airplane.

Flight 811 departed HNL gate 10 at 0133 Honolulu Standard Time (HST), 3 minutes after the scheduled departure time, with 3 flight crewmembers, 15 cabin crewmembers, and 337 passengers. The flightcrew attributed the short delay to cabin crew problems with arming the 5L cabin door emergency exit slide and the normal securing of the 2L door after a somewhat extended passenger boarding process. The second officer stated that all cabin and cargo door warning lights were out prior to the airplane's departure from the gate. He said that he

dimmed the annunciator panel lights at his station while the airplane was departing the gate area.

The captain was at the controls when the flight was cleared for takeoff on HNL runway 8R at 0152:49 HST. The auxiliary power unit (APU), which was used during the takeoff, was shutdown shortly after making the initial power reduction to climb thrust.

The flightcrew reported the airplane's operation to be normal during the takeoff and during the initial and intermediate segments of the climb. The flightcrew observed en route thunderstorms

both visually and on the airplane's weather radar, so they requested and received clearance for a deviation to the left of course from the HNL Combined Center Radar Approach Control (CERAP). The captain elected to leave the passenger seat belt sign "on."

The flightcrew stated that the first indication of a problem occurred while the airplane was climbing between 22,000 and 23,000 feet at an indicated airspeed (IAS) of 300 knots. They heard a sound, described as a "thump," which shook the airplane. They said that this sound was followed immediately by a "tremendous explosion." The airplane had experienced an explosive decompression. They said that they donned their respective oxygen masks but found no oxygen available. The airplane cabin altitude horn sounded and the flightcrew believed the passenger oxygen masks had deployed automatically.

The captain immediately initiated an emergency descent, turned 180(to the left to avoid a thunderstorm, and proceeded toward HNL. The first officer informed CERAP that the airplane was in an emergency descent and appeared to have lost power in the No. 3 engine. The appropriate 7700 emergency code was placed in the airplane's radar beacon transponder and an emergency was declared with CERAP at approximately 0220 HST. The No. 3 engine was shut down shortly after commencing the descent because of heavy vibration, no N1 compressor indication, low exhaust gas temperature (EGT), and low engine pressure ratio (EPR).

The second officer then left the cockpit to inspect the cabin area and returned to inform the captain that a large portion of the forward right side of the cabin fuselage was missing. The captain subsequently shut down the No. 4 engine because of high EGT and no N1 compressor indication, accompanied by visible flashes of fire. The flightcrew initiated fuel dumping during the descent to reduce the airplane landing weight.

The airplane was cleared for an approach to HNL runway 8L. The final approach was flown at 190 to 200 knots with the No. 1 and No. 2 engines only. During flap extension, the flightcrew observed an indication of asymmetrical flaps as the flap position approached 5(. The flightcrew decided to extend inboard trailing edge flaps to 10(for the landing. The right outboard leading edge flaps did not extend during the flap lowering sequence. The airplane touched down on the runway, approximately 1,000 feet from the approach end, and came to a stop about 7,000 feet later. The captain applied idle reverse on the Nos. 1 and No. 2 engines and employed moderate to heavy braking to stop the airplane. At 0234 (HST), HNL tower was notified by the flightcrew that the airplane was stopped and an emergency evacuation had commenced on the runway.

After the accident, UAL ramp service personnel, who had been involved with the cargo loading and unloading of flight 811 before takeoff from HNL, stated that they had opened and closed the forward cargo door electrically. They said that they had observed no damage to the cargo door. The ramp service personnel said that they had verified that the forward cargo door was flush with the fuselage of the airplane, that the master door latch handle was stowed, and that the pressure relief doors were flush with the exterior skin of the cargo door.

The dispatch mechanic stated that, in accordance with UAL procedures, he had performed a "circle check" prior to the airplane's departure from the HNL gate. This check included verification that the cargo doors were flush with the fuselage of the airplane, that the master latch lock handles were stowed, and that the pressure relief doors were flush or within 1/2 inch of the cargo door's exterior skin. He said a flashlight was used during this inspection.

The second officer stated that, in accordance with UAL Standard Operating Procedures (SOP) he had performed an operational check of the door warning annunciator lights as part of his portion of the cockpit preparation. The second officer also stated that he used a flashlight while performing an exterior inspection, again in accordance with UAL procedures. The exterior inspection was conducted while ramp service personnel were performing cargo loading operations and the cargo doors were open. He stated that he had observed no abnormalities or damage.

1.2 Injuries to Persons

Injuries Flightcrew Cabincrew Passengers Others Serious *Lost in flight. An extensive air and sea search for the passengers was unsuccessful.

1.3 Damage to the Airplane

The primary damage to the airplane consisted of a hole on the right side in the area of the forward lower lobe cargo door, approximately 10 by 15 feet large. The cargo door fuselage cutout lower sill and side frames were intact but the door was missing (see figures 1 and 2). An area of fuselage skin measuring about 13 feet lengthwise by 15 feet vertically, and extending from the upper sill of the forward cargo door to the upper deck window belt, had separated from the airplane at a location above the cargo door extending to the upper deck windows. The floor beams adjacent to and inboard of the cargo door area had been fractured and buckled downward.

Examination of all structure around the area of primary damage disclosed no evidence of preexisting cracks or corrosion. All fractures were typical of fresh overstress breaks.

Debris had damaged portions of the right wing, the right horizontal stabilizer, the vertical stabilizer and engines Nos. 3 and 4. No damage was noted on the left side of the airplane, including engines Nos. 1 and 2.

The right wing had sustained impact damage along the leading edge between the No. 3 engine pylon and the No. 17 variable camber leading edge flap. Slight impact damage to the No. 18 leading edge flap was noted.

There was a break and scuff in the wing leading edge aft of engine No. 4 and a scuff in the wing leading edge outboard of engine No. 4. There was a large indentation (to a depth of nearly 8 inches) in the area just above the outboard landing light, and the landing light covers were broken. There was a small puncture in the upper surface of the No. 14 Krueger flap and impact damage to the wing leading edge just aft of the No. 14 Krueger flap. There was a gash on the upper wing surface aft of the No. 14 Krueger flap and leading edge, as well as punctures to the wing leading edge aft of the number 16 Krueger flap. The under wing surface aft of the Krueger flaps also sustained impact damage.

The right wing also had sustained damage at the wing-to-body fairing and two flap track canoe fairings. Wing-to-body fairing damage was limited to surface scraping forward of and below the wing. The outboard surface of the No. 6 flap track canoe fairing revealed a slightly more significant gouge mark. The most severe damage was evident on the inboard surface of the No. 8 flap track canoe fairing, where three separate punctured areas were observed. The trailing edge flaps were not damaged.

The leading edge of the right horizontal stabilizer had several dents. The most severe dents, located 8 to 10 feet from the stabilizer root, were approximately 3 inches wide and 1 inch deep. No punctures were found. The vertical stabilizer had multiple small and elongated indentations with a maximum depth of 1/2 inch near the right base of the leading edge. A small gouge and two small scrapes were noted at midspan of the upper rudder.

A piece of cargo container was found lodged between the No. 3 engine pylon (inboard) and the wing underside. The piece of metal had severed the pneumatic duct for the leading edge flaps. Various nicks and punctures were evident on the inboard side of the No. 3 engine pylon. The No. 4 engine pylon had a small puncture near the leading edge of the wing.

The external surfaces of the No. 3 engine inlet cowl assembly exhibited foreign object damage including small tears, scuffs and a large outwardly directed hole. The entire circumference of all the acoustic (sound attenuator) panels installed on the inlet section of the cowl had been punctured, torn, or dented. None of the No. 3 engine cases were penetrated by objects, nor was there evidence of fire damage to any visible engine components and accessories. The

leading edges of all fan blade airfoils on the No. 3 engine exhibited extensive foreign object damage.

External damage to the No. 4 engine inlet and core cowls was confined to the inboard side of the inlet cowl assembly. The damage consisted of one major scuff mark, four lesser scuff marks and one crescent-shaped cut. The sound attenuator panels that were installed in the inlet area of the inlet cowl assembly had not been penetrated. The No. 4 engine fan blade airfoils had sustained both soft and hard object damage from foreign objects.

The cargo door separation resulted in the loss of fuselage shell structure above the cargo door, along with main cabin floor structure below seats 8GH through 12GH (see figure 3). The missing floor area extended inboard from the interior of the right side fuselage wall to the inboard seat track of seats 8GH through 12GH.

The supply and fill lines from the flightcrew oxygen bottle, and the supply line for the passenger oxygen system had been broken below the cabin floor inboard of the missing cargo door.

The two cabin pressurization out-flow valves, located on the underside of the fuselage, aft of the rear cargo compartment, were found fully open. The two over-pressure relief valves located on the forward left side of the airplane were found in the normal closed position. These valves were removed and bench tested. (See section 1.16.3, Pressurization System.) The majority of the cabin floor-to-cargo compartment blowout panels were found activated. The blowout panels are designed to relieve excess pressure differential following an explosive decompression to prevent catastrophic damage to the cabin floor structures.

The estimated damage to the airplane was \$14,000,000, based on UAL's costs to repair it.

1.4 Other Damage

No other property damage resulted from this accident.

1.5 Personnel Information

The crew consisted of 3 flight crewmembers (the captain, the first officer, and the second officer) and 15 cabin crewmembers. (See appendix B.)

1.6 Aircraft Information

1.6.1 General

On February 24, 1989, the United Airlines B-747 fleet consisted of 31 airplanes, including: 2 B-747-222B, 11 B-747-SP, 5 B-747-123, and 13 B-747-122 series airplanes. N4713U was equipped with four Pratt & Whitney model JT9D engines.

The accident airplane, serial No. 19875, registered in the United States as N4713U, was manufactured as a Boeing 747-122 transport category airplane by the Boeing Commercial Airplane Company (Boeing), Seattle, Washington, a Division of the Boeing Company. N4713U, the 89th B-747 built by Boeing, was manufactured in accordance with Federal Aviation Administration (FAA) type certificate No. A20WE, as approved on December 30, 1969. The airplane was certificated in accordance with the provisions of 14 CFR Part 25, effective February 1, 1965.

The maximum calculated takeoff weight for flight 811 was 706,000 pounds. The flight plan data showed an actual takeoff weight of 697,900 pounds. The center of gravity (CG) for takeoff was computed at 20.4 percent mean aerodynamic chord (MAC). The forward and aft CG limits were 12 and 29.7 percent MAC, respectively.

At the time of the accident, N4713U had accumulated 58,815 total flight hours and 15,028 flight cycles. N4713U had not been involved in any previous accident. Records indicated that the airplane had been inspected and maintained in accordance with the General Maintenance Program as defined in UAL Operations Specifications and in accordance with the FAA approved Aircraft and Powerplants Reliability Program. The records indicated that all required inspection and maintenance actions had been completed within specified time limits and all applicable airworthiness directives (AD) had been accomplished or were in the process of being accomplished, with the exception of AD 88-12-04, which was applicable to the B-747 lower lobe cargo door, and which had only been complied with partially. (See section 1.6.8 for explanation).

1.6.2 Cargo Door Description and Operation

Both the forward and aft lower cargo doors are similar in appearance and operation. They are located on the lower right side of the fuselage and are outward-opening. The door opening is approximately 110 inches wide by 99 inches high, as measured along the fuselage.

Electrical power for operation of the cargo door switches and actuators is supplied from the ground handling bus, which is powered by either external power or the APU. See figure 17 for a diagram of the cargo door electrical circuitry. The engine generators cannot provide power to the ground handling bus. APU generator electrical power to the ground handling bus is interrupted when an

engine generator is brought on line after engine start. The APU generator "field" switch can be reengaged by the flightcrew, if necessary on the ground, to power the ground handling bus. The air/ground safety relay automatically disconnects the APU generator from the ground handling bus, if it is energized, when the airplane becomes airborne and the air/ground relay senses that the airplane is off the ground.

The cargo door and its associated hardware are designed to carry circumferential (hoop) loads arising from pressurization of the airplane. These loads are transmitted from the piano hinge at the top of the door, through the door itself, and into the eight latches located along the bottom of the door. The eight latches consist of eight latch pins attached to the lower door sill and eight latch cams attached to the bottom of the door. The cargo door also has two midspan latches located along the fore and aft sides of the door. These midspan latches primarily serve to keep the sides of the door aligned with the fuselage. There are also four door stops which limit inward movement of the door. There are two pull-in hooks located on the fore and aft lower portion of the door, with pull-in hook pins on the sides of the door frame. (See figure 4 for cargo door components).

The cargo doors on the B-747 have a master latch lock handle installed on the exterior of the door. The handle is opened and closed manually. The master latch lock handle simultaneously controls the operation of the latch lock sectors, which act as locks for the latch cams, and the two pressure relief doors located on the door. Figure 5 depicts a lock sector and latch cam in an unlocked and locked condition.

Figure 4.--Boeing 747 lower lobe forward cargo door.

Figure 5.--Cargo door latch cam and lock sector in unlocked and locked positions.

The door has three electrical actuators for opening/closing and latching of the door. One actuator (main actuator) moves the door from the fully open position to the near closed position, and vice versa. A second actuator (pull-in hook actuator) moves the pull-in hooks closed or open, and the third actuator (latch actuator) rotates the latch cams from the unlatched position to the latched position, and vice versa. The latch actuator has an internal clutch, which slips to limit the torque output of the actuator.

Normally, the cargo doors are operated electrically by means of a switch located on the exterior of the fuselage, just forward of the door opening. The switch controls the opening and closing and the latching of the door. If at any time the switch is released, the switch will return to a neutral position, power is removed from all actuators, and movement of the actuators ceases.

In order to close the cargo door, the door switch is held to the "closed" position, energizing the closing actuator, and the door moves toward the closed position. After the door has reached the near closed position, the hook position switch transfers the electrical control power to the pull-in hook actuator, and the cargo door is brought to the closed position by the pull-in hooks. When the pull-in hooks reach their fully closed position, the hook-closed switch transfers electrical power to the latch actuator. The latch actuator rotates the eight latch cams, mounted on the lower portion of the door, around the eight latch pins, attached to the lower door sill. At the same time, the two midspan latch cams, located on the sides of the door rotate around the two midspan latch pins located on the sides of the door frame. When the eight latch cams and the two mid-span cams reach their fully closed position, electrical power is removed from the latch actuator by the latch-closed switch. This completes the electrically powered portion of the door closing operation. The door can also be operated in the same manner electrically by a switch located inside the cargo compartment adjacent to the door.

The final securing operation is the movement of lock sectors across the latch cams. These are manually moved in place across the open mouth of each of the eight lower cams through mechanical linkages to the master latch lock handle. The position of the lock sectors is indicated indirectly by noting visually the closed position of the two pressure relief doors located on the upper section of each cargo door. The pressure relief doors are designed to relieve any residual pressure differential before the cargo doors are opened after landing, and to prevent pressurization of the airplane should the airplane depart with the cargo doors not properly secured. The pressure

relief doors are mechanically linked to the movement of the lock sectors. This final procedure also actuates the master latch

lock switch, removing electrical control power from the opening and closing control circuits, and also extinguishes the cockpit cargo door warning light through a switch located on one of the pressure relief doors. Opening the cargo door is accomplished by reversing the above procedure.

The B-747 cargo door has eight (8) view ports located beneath the latch cams for direct viewing of the position of the cams by means of alignment stripes. Procedures for using these view ports for verifying the position of the cams were not in place or required by Boeing, the FAA, or UAL (see 1.17.5 for additional information).

Closing the door manually is accomplished through the same sequence of actions without electrical power. The door actuator mechanisms are manually driven to a closed and latched position by the use of a one-half inch socket driver. The door can also be opened manually with the use of the socket driver. There are separate socket drives for the door raising/lowering mechanism, the pull-in hooks, and the latches.

Operating procedures for the normal electrical operation of the forward and aft cargo doors are outlined in the UAL Maintenance Manual (MM). Authorization for deferral of maintenance on the door power system is contained in the UAL B-747 Minimum Equipment List (MEL). In addition, operating procedures for dispatching aircraft with an inoperative door electrical power system (manual operation) are specified in the operator's MEL.

The UAL MM differs from Boeing's recommended MM. UAL had modified Boeing printed material or replaced pages with their own methods and procedures for conducting maintenance functions. The modifications to the manufacturer's MM were accepted by the FAA through "approval" by the FAA Principal Maintenance Inspector (PMI). Electrical cargo door open/close operations in the UAL and Boeing MM's are approximately the same, except the final "Caution" statement differs in methods to ensure that the latch cams are closed:

United Airlines Maintenance Manual

CAUTION DO NOT FORCE HANDLE. LATCH CAMS NOT FULLY CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

Boeing Airplane Company Maintenance Manual

CAUTION DO NOT FORCE HANDLE. IF RESISTANCE IS FELT, CHECK LATCH ALIGNMENT STRIPES THROUGH VIEWING PORTS IN DOOR. LATCH CAMS NOT FULLY CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

The following step in Boeing's MM does not appear in the UAL MM: "Check that the Cargo Door Warning Light on flight engineer panel goes out." The UAL flightcrew checklist includes a check of the warning light as part of the cockpit procedures for dispatch.

Prior to the issuance of AD-88-12-04 (see 1.6.8), UAL ramp service personnel only operated the cargo doors electrically. Manual operation was accomplished only by maintenance personnel. AD-88-12-04 required the additional procedure of recycling the master latch lock handle following manual operation of the latch actuator.

1.6.3 UAL Boeing 747 Special Procedures--Doors

The Safety Board's investigation revealed that UAL had published a "special maintenance procedure" in the UAL MEL for manual operation of the cargo door. The Maintenance Manual Special Procedures, 5-8-2-52, dated January 1988, were incorporated into UAL's MEL for use by maintenance controllers and work foremen in issuing instructions or procedures to mechanics. The procedure allowed the use of a special 1/2-inch socket drive wrench as the primary tool for use in manually opening or closing the cargo door. The document further authorized, as an alternate tool, an air-driven torque-limiting screwdriver. UAL procedures required approval by San Francisco Line Maintenance and the station maintenance coordinator before an air-driven screwdriver could be used to operate the doors of a B-747 airplane with an inoperative cargo door power system.

At the Safety Board's public hearing, the FAA PMI and the FAA B-747 maintenance inspector for UAL testified that prior to the accident they were unaware of an FAA authorization for UAL's use

of an air-driven torque-limiting screwdriver on B-747 cargo doors. However, the FAA's approval for the use of the tool was noted in the MEL section of the airline's maintenance manual. The original approval had occurred before the current inspectors assumed their respective positions. Both testified that they had not reviewed UAL's B-747 MEL because they assumed that the previous inspectors had reviewed it.

According to UAL, the calibration/adjustment for the torque-limited air-driven screwdrivers was tested every six months. Safety Board investigators found no records for the calibration/adjustment of the power tools used to manually open and close UAL B-747 cargo doors.

The Safety Board received statements from UAL supervisory maintenance personnel at all UAL stations and contract facilities for B-747 operations indicating that air-driven screwdrivers had not been used by maintenance personnel to open or close the forward cargo door on N4713U in the months prior to the accident.

1.6.4 UAL Maintenance Program

Airplanes operated by UAL are maintained under an FAA-approved continuous airworthiness maintenance program, as required by 14 CFR Part 121, Subpart L. The requirements of the UAL maintenance program are detailed in their Operations Specifications, dated November 21, 1988. Generally, UAL has an overall in-house capability to perform virtually all of the maintenance required on its own airframes and powerplants. All of the required major airframe and powerplant maintenance for N4713U had been performed at the UAL maintenance facility in San Francisco, California.

UAL's maintenance and inspection program is scheduled either at specific flight hour or calendar intervals. These maintenance and inspection programs are designated as: Service No. 1, Service No. 2, or A, B, C, MPV, and D Checks.

The work scope of Service Checks consists of a general inspection of the airplane and engines, including servicing of consumable fluids, oxygen, and tire pressures. The Service No. 1 check involves an inspection at each maintenance facility where the airplane lands. The Service No. 2 check is performed at a maintenance facility where the airplane is scheduled for at least 12 hours of ground time. The maximum time interval between Service No. 2 Checks is not to exceed 65 flight hours.

The "A" Check is performed at intervals not to exceed 350 flight hours. This check includes an extended inspection of the cockpit, cabin, cargo

compartments, landing gear, tires, and brakes. It does not include a detailed inspection of the cargo doors.

The Phase Check ("B" Check) is scheduled on a calendar basis, not to exceed 131 days. The scope of the "B" Check contains items of inspection such as interior safety equipment and functional verification of various aircraft systems and components. It does not include a detailed inspection of the cargo doors.

The "C" Check is heavy maintenance oriented and is scheduled on a calendar basis, every 13 months. The "C" Check work scope is substantial and includes:

structural inspection items;

corrosion repair;

prevention and inspection of critical flight control systems; and,

a detailed inspection of the cargo doors.

The Mid-Period Visit (MPV) Check is a heavy maintenance inspection that is scheduled at intervals not to exceed 5 years. Items requiring scheduled overhaul are contained in the check as well as inspections of the airplane structure and interior.

The D Check, completes the routine scheduled B-747 maintenance plan and is scheduled at intervals not to exceed 9 years. The work scope is very similar to the MPV Check and consists of heavy maintenance to the airplane structure, landing gear, interior, and airplane systems, including the cargo doors.

1.6.5 Maintenance Records Review

A review of the airplane's history indicated that the forward and aft cargo doors were the original doors and neither had been removed for repair or replaced for cause. There was no record of major repair to either door or adjacent airplane structure.

The forward cargo door's forward mid-span latch pin had been removed because of gouging of the pin surface, during the last "C" check on

November 28, 1988. According to the available maintenance documents, including the most recent "D" check, a full cargo door rigging check had not been accomplished. UAL maintenance personnel indicated that no rigging of the forward or aft cargo doors was required during the following checks:

1. "D" check accomplished April 1984;
2. "C" checks accomplished November 11, 1987, and November 28, 1988; and,
3. "B" checks accomplished March 21, 1988 and July 27, 1988;

The records prior to the "D" check in 1984 and the "C" check accomplished in November 1987 were not required to be retained. This procedure complies with FAR 121.380.

The logbook of N4713U was reviewed and all numbered pages were in sequential order with none missing. The airplane had been released for flight by UAL, HNL Maintenance, in accordance with UAL procedures. The Los Angeles to HNL segment of flight 811, on February 23, 1989, generated four logbook discrepancy entries. All items were cleared by HNL maintenance and none were related to the cargo door. No new deferred items were generated and no current deferred items were corrected. The Maintenance Release document for flight 811 indicated that all deferred items were in accordance with the UAL Minimum Equipment List (MEL) and none referenced the forward cargo door.

UAL stores its maintenance information in an "electronic logbook," entitled Aircraft Maintenance Information System (AMIS). This system tracks on a daily and worldwide basis the flightcrew defect reports, all nonroutine maintenance defects, and maintenance corrective actions for the UAL airplane fleet. The system follows an Airline Transport Association (ATA) chapter format. According to UAL, the AMIS information is used as part of UAL's FAA approved maintenance reliability program affording the capability to assess trends at any given time.

A complete history of N4713U was reviewed for the following ATA Chapters:

Chapter-00-Miscellaneous

No significant items associated with the cargo door systems.

Chapter-21-Air Conditioning and Pressurization

An entry, dated August 19, 1988, indicated "Auto and Standby pressure controllers were erratic."

UAL maintenance cleared this item as "Checked per Maintenance Manual Chapter (MM) 21-31-00.

Chapter-31-Instruments (Not related to any specific system)

No significant items associated with the cargo door systems.

Chapter-52-Doors (Cargo door section only)

During the period September 7, 1988, through November 1, 1988, a series of five discrepancies on the forward cargo door's electrical opening and closing system were noted. Ground handling personnel were required to operate the door by the manual system. On November 1, 1988, UAL maintenance corrective action for this discrepancy was signed off as, "replaced power unit [lift mechanism] per Maintenance Manual Chapter 52-34-02.

An expanded AMIS history of the N4713U forward cargo door system was prepared beginning December 1, 1988, and continuing until the date of the accident. The history tracked the airplane by each flight and station transited.

During the period December 5, 1988, through December 23, 1988, eight defect reports regarding the opening and closing of the forward cargo door were entered into the system. The reported defects involved problems with the cargo door not always operating with the normal electrical system. Appendix E contains the details of the writeups and corrective actions.

During the period December 23, 1988, through February 23, 1989, two forward cargo door discrepancies were noted on N4713U. On January 3, 1989, the discrepancy was, "Manual lock

seals broken." The corrective action was signed off as, "recycled [door] per placard on door and documented. No door

problems." On January 15, 1989, the discrepancy was, "cargo door seal, lower aft corner is torn and loose from retainer." The corrective action was "repaired seal." There were no further recorded discrepancies.

On February 23, 1989, a written discrepancy noted "Aft cargo door damaged aft lower corner." The corrective action listed, "Interim repair per (EVA) LM-8-433. Accomplish permanent repair within 60 flight hours."

Chapter-53-Structures (Fuselage)

During the period March 1988, through February 24, 1989, one defect was noted for each of the forward and aft cargo doors on N4713U.

Forward Cargo Door.--On September 6, 1988, the discrepancy was, "Approximately six inches of forward cargo door jamb damaged center of lower side sealing surface." The corrective action was, "Installed doubler and sealed area."

Aft Cargo Door.--On April 22, 1988, the discrepancy was, "Aft cargo door rear sill latch does not spring up to lock." The corrective action was, "Replaced latch."

1.6.6 Service Difficulty Report Information

A review was made of the Service Difficulty Reports (SDRs) for ATA Chapter 52 for all UAL Boeing 747 airplanes. Thirty-nine SDRs were recorded over the period January 31, 1983, through March 21, 1989. The following summarizes data concerning the forward and aft cargo doors:

cases of corrosion;

cases of cracking;

cases of door open (false) indications;

cases where cabin did not pressurize;

cases of cabin pressure loss; and

case of dent caused by ground equipment.

None of the noted SDR cases were recorded for N4713U.

1.6.7 Service Letters and Service Bulletins

Boeing issues information to its customers via Service Letters (SL's) and Service Bulletins (SB's) to inform operators of reported and anticipated difficulties with various airplane models. Twelve SL's provided guidance for maintenance or information applicable to the B-747 cargo doors. Twenty-nine SB's provided guidance for maintenance or information applicable to the B-747 cargo door.

SB-747-52-2097, "Pressure Relief Door Shroud Installation--Lower Lobe and Side Cargo Doors," was issued on June 27, 1975. Revision 1 to SB-747-52-2097 was issued November 14, 1975. In general, the SB recommended the installation of shrouds on the inboard sides of the cargo door pressure relief door openings. The purpose of the shrouds was to prevent the possibility of the pressure relief doors being rotated (blown) to the closed position during the pressurization cycle. This condition could only occur if the master latch lock handle had been left open and the flightcrew failed to note the cargo door open warning before takeoff.

UAL records for N4713U indicated that SB-747-52-2097 had been complied with and the shrouds had been installed on the forward and aft cargo doors. However, examination of the aft cargo door on N4713U revealed that the shrouds were not in place. UAL could not find records to verify if the shrouds had been installed or if they had been removed from either door.

1.6.8 Airworthiness Directives

There had been 141 Airworthiness Directives (ADs) issued that were applicable to the accident airplane. Two ADs were pertinent to the cargo door. AD 79-17-02-R2 ("Inspection of Fore and Aft Lower Cargo Door Sill Latch Support Fittings,") required an inspection every 1,700 flight hours. The second, AD 88-12-04 ("To Insure That Inadvertent Opening Of The Lower Cargo Door Will Not Occur In Flight,") issued on May 13, 1988, required an initial one time inspection of the cargo door latch locking mechanisms within 30 days of issuance of the AD, and certain repetitive

inspections until terminating action for the AD was taken.

The circumstances of a Pan American World Airways (Pan Am), Boeing 747-122 cargo door opening in flight (see 1.17.1 for details) led to the issuance of Boeing Alert Service Bulletins (ASB) 52A2206 on April 8, 1987, and 52A2209 on August 27, 1987, entitled, "Doors - Cargo Doors Lower Lobe Forward

and Aft Cargo Doors, Latch Locking System Tests, Operation and Modification." Tests and investigation revealed that latch lock sectors would, in some instances, not restrain the latch cams from being driven open manually or electrically. Movement of the latch cams without first moving the lock sectors to the stowed [unlocked] position would cause bending, gouging, and breaking of the sectors. The FAA issued AD-88-12-04 to make the provisions of SB's 52A2206 and 52A2209 mandatory.

The terminating action for AD 88-12-04 called for installing steel doublers to add strength to the lock sectors to prevent the latch cams from being able to be driven to the open position manually or electrically with the sectors in the locked position. AD 88-12-04 also required that, if the door could not be operated normally (electrically), a trained and qualified mechanic was to open and close the door manually, rather than ramp service personnel. Further, the AD required an inspection of the lock sectors for damage once a cargo door was restored to electrical operation after any malfunction had required manual operation of the door. The amount of time allowed for completing the terminating action portion of AD 88-12-04 was either 18 months or 24 months, from the issue date of the AD, depending on the Boeing 747 model series. Terminating action for the AD had not been accomplished on N4713U prior to the accident, nor was it required since, for this airplane, the deadline for compliance with the terminating action was January 1990. According to UAL, N4713U was scheduled for completion of the terminating action in April 1989, when the airplane was scheduled for other heavy maintenance.

During the Safety Board's investigation it was determined that a clerical error was made by UAL personnel, while attempting to expedite the processing of an advanced copy of a Notice of Proposed Rulemaking (NPRM 87-NM-148-AD), preceding AD 88-12-04. The error involved the omission of one line of text during the typing of the document. Because of that error, the portion of the text of the NPRM (and the final text of the AD) was left out of UAL's maintenance procedures. The omitted text required an inspection of the B-747 cargo door lock sectors every time a cargo door was restored to normal (electrical) operation after manual operation was required.

The UAL maintenance internal auditing system, including quality assurance personnel, did not detect the omission until after the accident. UAL personnel stated that, for unknown reasons, no one within the maintenance or quality assurance programs had reviewed the final AD language for comparison with the UAL maintenance procedure.

A review by Safety Board investigators of forms used by UAL to verify compliance with applicable FAA AD's issued indicated that all of the applicable mandatory ADs were satisfied within their specified time limits. The list provided by UAL to the FAA as part of the FAA's oversight responsibilities showed compliance with AD-88-12-04, with the exception of the terminating action.

Section 1.17.3 contains information relevant to the B-747 cargo door corrective actions taken since the accident.

1.7 Meteorological Information

The accident occurred in night visual meteorological conditions. No adverse weather was experienced, although the flight did have to deviate around thunderstorms during the descent.

1.8 Aids to Navigation

There were no navigational problems.

1.9 Communications

There were no radio communication difficulties between flight 811 and air traffic control (ATC). Members of the flightcrew did not have any difficulty in verbally communicating with each other; however, attempts to communicate with the cabin crewmembers by interphone were unsuccessful

following the explosive decompression.

1.10 Aerodrome Information

After the explosive decompression, the airplane returned to HNL, a 14 CFR Part 139 certificated airport on the island of Oahu, Hawaii. The airport is located about 4 miles west of Honolulu, Hawaii.

HNL is a "joint use" airport that is used by the State of Hawaii, the U.S. Air Force, general aviation, commercial, air carrier, air taxi, and military aircraft. Aircraft Rescue and Fire Fighting (ARFF) services are provided by State and Hickam Air Force Base ARFF units. Prior to the emergency landing at Honolulu, flight 811 requested that all available rescue and medical equipment to

be on hand when they landed. When the crash alarm was broadcast, all civilian and military fire units responded and were in position in 1-minute at pre-designated stations at runway 8 left.

The Safety Board's investigation revealed that there was no direct radio communications between the State Airport vehicles and Hickam ARFF vehicles. Because there were no direct radio communications, the Chief of the airport's units had to drive his vehicle to the vehicle of the Chief of the Hickam units to coordinate the positioning of ARFF units prior to the landing of United 811. The Hickam vehicles are painted olive drab camouflage. During the response, the Chief of the State ARFF vehicles observed a near collision between a State and a Hickam vehicle. He attributed this to the camouflaged Hickam vehicle not being visually conspicuous in spite of the fact that each of the vehicles had a red rotating beacon operating. The response took place on a moonless night and in light rain.

1.11 Flight Recorders

The airplane was equipped with a Sundstrand model 573 digital type Flight Data Recorder (DFDR) and a Sundstrand model AV557-B Cockpit Voice Recorder (CVR).

Examination of the data plotted from the DFDR indicated that the flight was normal from liftoff to the accident. The recorder operated normally during the period. However, the decompression event caused a data loss of approximately 2 1/2 seconds. When the data resumed being recorded, all values appeared valid with the exception of the pitch and roll parameters. Lateral acceleration showed a sharp increase immediately following the decompression. Vertical acceleration showed a sharp, rapid change just after the decompression and a slight increase as the airplane began its descent.

The CVR revealed normal communication before the decompression. At 0209:09:2 HST, a loud bang could be heard on the CVR. The loud bang was about 1.5 seconds after a "thump" was heard on the CVR for which one of the flightcrew made a comment. The electrical power to the CVR was lost for approximately 21.4 seconds following the loud bang. The CVR returned to normal operation at 0209:29 HST, and cockpit conversation continued to be recorded in a normal manner.

1.12 Wreckage and Impact Information

An extensive air and surface search of the ocean conducted immediately following the accident failed to locate the portions of the airplane lost during the explosive decompression. However, the Safety Board, as well as other parties to the investigation, pursued several avenues to search for and recover the cargo door.

Navy radar near Honolulu tracked debris that fell from the airplane when the cargo door was lost. Refinement of the radar data led to a probable "splashdown" point in the ocean. Further assistance from the Navy regarding the ocean currents and drift information led to a probable location of the cargo door and associated debris on the ocean floor.

The undersea search operation was begun on July 22, 1990, using the Orion, a state-of-the-art Navy side-scanning sonar "fish." Searching in the area selected by analysis of radar data and undersea currents, the Orion located a debris field on its first pass over the 14,200-foot-deep ocean floor. The second pass located a significant sonar target, which later analysis indicated was probably the cargo door. Since the Orion is only capable of searching, the debris field was marked with transponders for use during the subsequent recovery phase.

On September 14, 1990, the recovery ship Laney Chouest sailed from Pearl Harbor with the manned, deep-sea submersible Sea Cliff. Safety Board, FAA, Boeing, and UAL engineering staff assisted the recovery team aboard the Laney Chouest. After four dives in the area previously identified as the debris field, only pieces of cargo container and other small debris from the airplane had been recovered. (It appears that the significant target identified by the Orion was a piece of cargo container rather than the cargo door.) On the following dive, however, the lower portion of the cargo door was located and recovered. The fuselage structure above the cargo door was located and raised to the surface on the sixth dive, but heavy seas prevented its recovery. The upper portion of the door was recovered during the Sea Cliff's seventh dive on October 1, 1990. Afterward, it was decided that no further effort could be justified to recover the fuselage structure above the cargo door, and the recovery mission was terminated.

Following recovery of the cargo door, each piece was sprayed with a corrosion inhibitor. The ship promptly returned to Pearl Harbor, and the retrieved door portions were removed and examined before being shipped to Seattle, Washington, for detailed examinations under the supervision of Safety Board staff.

Visual examinations on the recovery ship and in Pearl Harbor confirmed that the cargo door lock sectors were in the locked position and that the latch cams were in the nearly open position. Figure 6 depicts the position of the lock sectors and cams as recovered from the ocean. There was no evidence of progressive fractures in the door structure.

The cost for the search mission was \$193,000, and the cost for the recovery mission was \$250,000. These costs were shared by the Safety Board, the FAA, UAL, and Boeing. Section 1.16 contains information on the examination of the recovered wreckage.

1.13 Medical and Pathological Information

Appendix D contains a list of injuries.

1.14 Fire

There was no fire in the cabin or fuselage. The fires in engines No. 3 and 4 were extinguished after the engines were shut down.

1.15 Survival Aspects

The fatal injuries were the result of the explosive nature of the decompression, which swept nine of the passengers from the airplane.

At 0210, the FAA notified the U.S. Coast Guard that a United Airlines, Inc., B-747, with a possible bomb on board, had experienced an explosion and was returning to HNL. The Coast Guard Cutter, Cape Corwin, departed Maui at 0248 to search the area for debris and the missing passengers. Ultimately, 4 shore commands, 13 surface/air units, and approximately 1,000 persons took part in the combined search and rescue (SAR) operation. The search was terminated at 1200 on February 26, 1989, without recovery of any passenger bodies.

The flight attendants had approximately 20 minutes to prepare the cabin and the passengers for an imminent ocean ditching, and subsequently, for an emergency evacuation. During the 20 minutes they attended to injured flight attendants and passengers, attached the face masks to their emergency oxygen bottles, helped each other don life preservers, helped numerous passengers don life preservers, held up safety cards and life vests to call attention to these items for passengers to use, briefed "helper" passengers to assist in the evacuation, cleared

debris away from the exit doors and aisles, closed the doors of the storage compartment above doors 2 left and 2 right, prepared the cabin for an emergency evacuation, and told the passengers to brace for impact.

Several problems were experienced by the flight attendants and the passengers following the decompression, while preparing for a possible ditching, and preparing for the emergency evacuation. These problems included difficulties encountered by flight attendants in connecting face masks to their portable oxygen bottles, the lack of a sufficient number of megaphones, limited visibility from a flight attendant seat, overhead storage compartment doors opening, and donning and fastening life preservers.

Federal Aviation Regulation 14 CFR 25.1447 (c)(4) requires that "portable oxygen equipment must be immediately available for each cabin attendant." Those portable oxygen bottles on N4713U, which were readily available, were not immediately usable because the masks were not attached to the regulators. The flight attendants reported difficulties in attaching the masks to the regulators.

The aft purser ran back to the flight attendant jumpseat at door 5-left for a portable oxygen bottle. However, she found no bottle at this location (none was installed). She then ran back to the 4-left jumpseat, by which time she was "light headed." After the aft purser reached jumpseat 4-left, flight attendant No. 14, who was already sitting there, placed an oxygen mask on her face. The aft purser further stated, "considering the fact that in this case there was no other available source of oxygen, you can't imagine how horrible I felt going back there needing oxygen but finding no oxygen bottle at 5-left. It was terrifying."

A portable emergency oxygen bottle was not required to be stowed at the flight attendant seat at exit 5-right; however, one was stowed in the right coat closet behind the flight attendant seat. In addition, the left side closet and rest rooms were physically separated from the right side closet and rest rooms. This arrangement requires a flight attendant, who was seated at exit 5-left to walk around to the right side of the cabin to obtain the oxygen bottle.

Communication between the flight attendants and passengers was very difficult because of the high ambient noise level in the cabin after the decompression, even though the public address (PA) system was operational. Flight attendants were located at each of the 10 exit doors, yet there were only two

megaphones required to be on the airplane; one located at door 1-left and another located a 4-left. The flight attendants, who were responsible for each of these two doors, used the megaphones to broadcast commands to passengers in their immediate areas and to other flight attendants in preparation for the landing and subsequent evacuation. The other 13 flight attendants (including the one deadheading flight attendant) had to shout, use hand signals, and show passengers how to prepare for the evacuation by holding up passenger safety cards, so passengers could review the information and also know how to put on their life preservers.

As soon as the decompression occurred, the flight attendant in the upper deck business class section went to her jumpseat and donned her oxygen mask, life preserver, and restraint system. While she waited for instructions, and because of intense cabin noise she had to communicate with passengers by holding up a safety card and a life preserver. Passengers sitting in the front rows, in turn, showed safety cards and life preservers to other passengers seated behind them. Eventually everyone understood that they were to read the safety card and put on their preservers. However, the 5 foot 3 1/2 inch flight attendant stated that her jumpseat was so low that she could not directly observe the passengers in the 4th row (last).

A two door overhead stowage compartment that had formerly stored a life raft was located above each exit door. These compartments contained blankets and passenger carry-on luggage. At doors 2-left and 2-right the doors of each compartment had opened downward and blocked each exit. Also the contents of the compartments fell to the floor at the exits. The doors had to be closed before the evacuation because they partially blocked the exit.

The chief purser was not able to tighten the life preserver's two straps around her waist and needed the deadheading flight attendant to tighten them for her. Several flight attendants and passengers had difficulties connecting the two straps around their waists. One flight attendant helped about 36 passengers don their preservers.

Safety Board investigators and United Airlines personnel examined several life preservers from each of the types of preservers produced by five manufacturers. The strap of one manufacturer's preserver was very difficult to tighten around the waist while another from the same manufacturer was easy to

tighten. The two vests had different strap material and strap adjustment fittings. Also, the straps are very difficult, if not impossible, to tighten when they are pulled at an acute angle from the

wearer's body, i.e. from about 45 to 70 degrees. Holding the hands and straps closer to the waist facilitates easier adjustment of the straps.

1.16 Tests and Research

1.16.1 Cargo Door Hardware Examinations

1.16.1.1 Before Recovery of the Door

The following forward cargo door closing and latching components were returned to the Safety Board's Materials Laboratory for analysis after they were documented in place on the airplane:

Two pull-in hook pins, one from the lower end of the forward side of the door body cutout forward frame, and one from the lower end of the aft side of the body cutout aft frame, with housings;

Two mid-span pins, one from the forward side of the door body cutout forward frame, and one from the aft side of the door body cutout aft frame.

All components were initially examined while installed on the airplane. All eight forward cargo door latch pins, with housings, were removed for further laboratory examination. Also, for comparison, one of the latch pins, with housing, from the aft cargo door was also removed. For orientation purposes, the eight lower latch pin assemblies are referred to by number, with the No. 1 latch pin being the most forward on the lower door sill, and the No. 8 pin being the most aft. When referencing a circumferential location on the latch pins or mid-span pins, a clock position was used. The clock code was oriented looking forward with 12 o'clock being straight up and 9 o'clock being directly inboard.

Based on the orientation of the latching mechanisms, the fully unlatched latching cams would first contact the latch pins from about the 1:15 o'clock position to the 7:15 position as the door was closed. As the cams are being latched around the pins, they would rotate approximately 80°, making contact with the pins from about the 4:15 position to the 10:15 position (See figure 7).

Detailed examination of the exposed surface of the pins (the portion of the pins extending from the housings) revealed various types of wear and damage. In general, all of the forward door cargo latch pins had smooth wear over the entire portion of the pin area contacted by the cams during normal closing and opening of the door. The pins also had distinct roughened (smeared) areas between the 6:15 and the 7:30 positions (See figure 8). The roughened areas had evidence of "heat tinting" and transfer of cam material to the surface of the pins. On pins 1 and 8 the roughened areas extended past the pin bottom to the 5:00 position. The 7:30 position approximately corresponds to the area on the pin where the lower surface of the cam would be relative to the pin when the latch cams are in the unlatched or nearly unlatched position.

The forward pull-in hook pin was not significantly bent, but the structure to which it was attached was deformed outward, so the hook pin was deflected significantly outward. Three of the four bolts holding the aft pull-in hook pin had sheared, so the hook pin was also deflected outward. Both hook pin ends were damaged, but neither pin was significantly deformed along its length. There was significant heat tinting on the damaged area of the forward hook pin. Boeing engineering calculations determined that the pull-in hook pins would fail at a 3.5 psi differential cabin pressure with the latch cams unlatched.

The forward mid-span latch pin was relatively undamaged. The aft mid-span latch pin had definite areas of damage. Both pins had wear areas where the cams would contact the pins during latching.

1.16.1.2 After Recovery of the Door

The documentation of the recovered cargo door was divided into four areas: 1) door structure, 2) master latch lock system, 3) latch system, and 4) hook system. A description of the recovered door follows.

1. Door Structure:

The cargo door had fractured longitudinally near the mid-span lap joint near stringer 34R, just beneath the mid-span torque tubes. Except for an area of missing skin between frames 2 and 3 and a portion of frame webs where the upper latch lock torque tube had torn out, the frames and skin of the upper door

piece mated to the lower door piece.2 Several areas of the upper door skin along the longitudinal fracture were bent back. In addition, a large area of lower door skin between frame 6 and the aft door edge had peeled downward from the fracture line. The two door pieces are shown together in Figures 9 and 10. Examinations of the fracture surfaces of the skin and frames revealed no evidence of pre-existing cracks. All fractures were typical of overstress separation.

Seven of the eight lock sector slots in the lower beam showed evidence of contact and scraping by the lock sectors. Only the No. 1 lock sector slot was undamaged, although the bracket forward and above the No. 1 slot did appear to have been damaged by contact from the lock sector (slots numbered 1-8, forward-aft). The direction of the scraping on the slots could not be determined conclusively.

The decal covering the latch actuator manual drive port was found broken circumferentially around the edge of the port cover, which was loose and rotated from its normal position (See figure 11). There was an impression in the decal similar to a Phillips-head screw slot in line with the center of the retainer screw securing the cover. There was also a 0.06-inch-long linear slit from 10 to 4 o'clock approximately centered over the retainer screw head (See figures 12 and 13). There was no rotational tearing and no loss of decal material in the area covering the screw head location. During examinations of the door at Boeing, it was noted that the retainer bracket on the inside of the latch actuator manual drive port cover was bowed outward; the port cover was not deformed. The retainer bracket on the inside of the hook actuator manual drive port cover was similarly bowed outward, and the port cover was bowed outward.

The hinge that attaches the cargo door to the fuselage is comprised of several hinge sections--those attached along the upper edge of the cargo door and those along the fuselage just above the cargo door cutout--interconnected with hinge pins. The hinge pins and all hinge sections from N4713U's forward cargo door were intact; all hinge sections rotated relatively easily. All attach bolts from the hinge sections on the door remained attached; conversely, no bolts remained attached to the hinge sections on the fuselage. Several areas on the hinge sections, such as the fuselage hinge sections, showed evidence of contact from the door during overtravel (See figure 14). In addition, the fuselage forward hinge sections

were slightly bent. The upper flange of the door, to which the door hinges are attached, was not deformed. The forward cargo door can rotate open 143 degrees before the hinge would deform, permitting the door to contact the fuselage above.

Examination of the outer skin contour of the upper door piece revealed that it had been crushed inward. There were also many areas on the outer skin where blue and red paint transfer marks could be seen. These marks were generally forward of the aft pressure-relief door, and the blue marks were located above the red marks. The UAL paint pattern incorporates red and blue stripes along the fuselage above the cargo door. Figure 15 is a plot of the documented paint marks on the upper door piece.

There was no evidence of the pressure relief door shrouds found on the forward door; however, most of the inner door lining to which the shrouds attach was missing.

2. Master Latch Lock System:

All eight lock sectors were found in the locked position--actually past the fully locked position. They had been pulled through the lock sector slots in the lower beam of the cargo door. (When they are fully locked, the lock sectors should be recessed in the lower beam approximately 3/8 inch). All lock sectors had deflected off the high shoulder of the latch cams due to interference with the partially unlatched cams. Prior to disassembly of the components, the interference between the cams and the lock sectors was removed by rotating the cams to the latched position.

Examination of the lock sectors disclosed that the bottom of the lower arm of each lock sector was gouged. For seven of the eight lock sectors, the distance from the main gouge area to the location of the interference between the latch cam and the lock sector was approximately 0.75 inch. (The No. 2 lock sector was corroded and had fractured at the location of the large gouge common to the other seven lock sectors. Consequently, it was not in contact with the No. 2 latch cam when the

door was retrieved).

The master latch lock handle housing and trigger were found relatively flush with the door outer skin. The top of the handle was recessed approximately 0.50 inch inward from flush, and the bottom of the handle was protruding approximately 0.40 inch outward from flush (See figure 16). This

Figure 15.--Documented paint marks on outer skin of upper door piece. Dashed line is approximately 8 degrees from horizontal.

position of the handle indicates that the lock sectors were in a position past fully locked. The fuse pin was found in three pieces but was heavily corroded. The handle housing was undamaged.

Two of the three connecting rods between the master latch lock handle and the lock sector torque tube were bowed slightly, but they were otherwise intact. No deformation was observed on any section of the lock sector torque tube, although one of the six bearings assembled on the torque tube had been damaged. The No. 3 bearing inner race and its torque tube locator sleeve were displaced forward approximately 0.20 inch from the bearing housing centerline. The outer race was broken and pushed forward out of the housing.

The lower two connecting rods between the lock sector torque tube and the torque tube below the pressure-relief doors were undamaged; however, the upper connecting rod had separated at the upper, tapered end. The torque tube below the pressure-relief doors were missing, and the pressure-relief door connecting rods had separated at the lower, tapered end. The remaining portion of each rod was undamaged, but the forward pressure-relief door was jammed open into the cutout.

3. Latch System:

All eight lower latch cams were found in a nearly unlatched position, and all of them were binding against the lock sectors except the No. 2 cam (lock sector No. 2 had broken). Latch cams 1-6 were approximately 62 degrees from the fully latched position, and cams 7 and 8 were approximately 70 degrees from fully latched. Full rotation of the latch cams is 80 degrees.

Several of the lower latch cams contained compression and smearing damage on the lower lip of the latch cam cavity ("lower" relative to an open cam). This damage is consistent with the forceful movement of the cams across the latch pins.

The four rods between the latch actuator torque tube and the four bellcranks containing the latch cams were attached and undamaged. No section of the latch actuator torque tube was damaged, and the bearings/supports along the tube were intact. The latch actuator was removed and later disassembled. No anomalies were found.

4. Pull-in Hook System:

The forward and aft pull-in hooks were found near the closed position. Both of them exhibited wear patterns consistent with contact with the pull-in hook pins during door operation. For both the forward and aft hooks, the inboard edge of the pull-in hook channel contained compression and smearing damage consistent with a forceful movement of the hooks over the pins while the hooks were in the closed or nearly closed position.

1.16.2 Forward Cargo Door Electrical Component Examinations

1.16.2.1 Before Recovery of the Door

Several electrical components associated with the operation of the forward cargo door were examined on the airplane and were then removed for further testing. These components included the No. 2 ground handling power bus relay, the air/ground safety relay, the No. 1 auxiliary power circuit breaker, and the outside and inside door control switches. All of these components were tested for both single faults and intermittent failures. The test results showed that all of the switches/relays were functional, although a loose wire connection was found on the outside door control switch. This loose wire connection showed evidence of overheated insulation on the two terminal lugs that attach to terminal No. 5, and there was evidence of a burn (arc point) on the top of the screw head for terminal No. 5. Terminal No. 5 is associated with power for the door "close" cycle, and not the door "open" cycle.

An electrical continuity check was performed on the cockpit cargo door warning light system components that remained with the airplane. This check confirmed the integrity of the circuit from the door area to the cockpit. The examination of the two bulbs that comprise the forward cargo door warning light revealed that one bulb was inoperative. The other bulb, which is in parallel with the inoperative bulb, was found operative. The illumination of the display legend, which reads "FWD CARGO DR" on the flight engineer's panel, was discernible with one bulb inoperative. A functional check of the circuit, which allows the cockpit warning lights to be dimmed during night operations, was also performed. The check consisted of removing the card containing this circuit and installing it in another B-747. The test was satisfactory in that the dim/bright circuit functioned properly.

1.16.2.2 After Recovery of the Door Switches--General

The cargo door was recovered with all of its position sensing switches installed in their proper locations. The electrical junction box was found attached to the door but damaged. The switches recovered and examined were: S2 Master Latch Lock; S3 Door Warning; S4 Latch Close; S5 Hook Position; S6 Fwd Mid-Span Latch Open; S7 Door Close; S8 Hook Close; and S9 Aft Mid-Span Latch Open. Figure 17 provides a diagram of the cargo door's electrical circuitry.

Five of the eight position-sensing switches installed on the door had evidence of external damage to the switch housing. The damage on four switches (S2,S3,S4,S8) consisted of primarily compression dimpling on the housing. The S5 switch exhibited mechanical impact damage on the switch housing and mounting bracket. The striker assembly for switch S8 was loose (2 of 3 rivet fasteners sheared). The electrical wiring recovered with the door exhibited signs of tensile separation from overload at all failure points examined.

Each switch was photographed and its installed position was documented. Electrical continuity readings were taken with an ohmmeter across the poles of each switch at the first point of wire separation as found on the door. After the readings were recorded, all switches were removed from the door so that photographs and x-rays of each switch could be taken. Electrical continuity readings were retaken.

Disassembly of each switch consisted of: (1) drilling two holes in the switch housing to release trapped water from the switch (2) cutting a small window in the switch housing to examine the internal basic switches (3) removing the housing, (4) removing the internal bracket, and (5) removing basic switch covers.

During the drilling step, water was released from every switch when the holes were drilled in the switch housing. The water was filtered into a glass container. The quantity was not measured but appeared to be less than 5 mL. The residue from the filtered water trapped on the filter media had a blue-green color.

After the switch housing was removed, an ohmmeter was connected across the 1-2 poles of the switches that would not transfer electrical continuity (S2,S3,S4,S6,S7) when actuated. The rivets were then drilled out of the internal bracket. After the last of the two rivets were drilled out, the switch contacts

Figure 17b.--Diagram of cargo door electrical circuitry.

transferred to the other pole on S2, S3, and S4. On S6, the used basic switch was held closed by its plunger. S7 transferred after the switch housing and water inside were removed.

During removal of the basic switch covers, a trend was noted in the discoloration of some of the basic switches. The used switch had a reddish-brown coloration. The unused switch was not discolored.

Each switch was found to be wired correctly to its poles and through its contacts within the basic switches. All contacts operated with light finger pressure after removal of the basic switch covers. There was no evidence of pitting, excessive corrosion, or heat distress in the contacts of any of the switches. The following sections detail pertinent observations concerning each switch.

The S2 master latch lock is given particular significance because of its function to protect against

inadvertent door operation and is thus described in more detail. It is a single-pole double-throw (SPDT) switch used to sense the unlocked position of the door lock sectors. The switch is mounted in the aft lower corner of the door. A bracket attached to the No. 7 lock sector depresses the switch when the door lock sectors are rotated to their unlocked position. When the bracket attached to the lock sector contacts the switch plunger and depresses it, the circuit path through the switch is closed and 28VDC electrical control power to the door is established. When the force on the plunger is relaxed, the circuit is opened and 28VDC electrical control circuit is removed.

The wires leading to the S2 switch had been cut by the team after the recovery in an attempt to test continuity through the switch. The door recovery team reported that it found continuity through the 1-3 contacts but not through the 1-2 contacts. The switch plunger was actuated by the recovery team. The recovery team noted that the switch did not transfer continuity during these tests. The operation of the switch plunger would normally transfer continuity. Subsequent detailed examination of the S2 switch confirmed the findings of the recovery team.

The area around the upper face of the internal bracket was bent toward the basic switches and had evidence of corrosion residue. The bracket was found broken. The switch contacts transferred from the 1-3 actuated position to the 1-2 nonactuated position when the bracket was removed. Scanning electron

microscope examination of the fracture surfaces revealed evidence of overload and corrosion.

The external switch housing was dented. The final examination performed on the switch consisted of removing the plastic covers on the basic switches. Prior to removal of the basic switch covers, it was noted that the cover to the used basic switch was cracked. The contacts functioned normally when exercised by light finger pressure.

Microscopic examination revealed a black discoloration near one of the lower contact posts of the used basic switch. Energy dispersive spectrometric examination of the residue disclosed the presence of gold, iron, magnesium, sodium, and chlorine. No mechanical or electrical anomalies were detected with the basic switch contacts.

Additional testing was performed by Boeing on switches of a similar design to those used on the accident airplane's cargo door. The testing was conducted to identify conditions that would result from salt water immersion at a pressure depth of 14,200 feet for 18 months. The testing verified that external damage to the switch housing occurred at pressure depths of 7,000 feet and greater. Switch seal leakage and subsequent internal corrosion was also noted. None of the testing performed by Boeing duplicated internal switch damage that caused basic switch contact closure or internal damage to the switch support bracket.

Wiring:

The electrical wiring recovered with the cargo door was documented in place before being removed for further tests. About 40 percent or 112 feet of wire from the original length of approximately 274 feet was recovered and examined. Of this amount, about 46 feet of wire installed in the aircraft forward of the cargo door was not examined. Most of the wires leading from the door to the fuselage were not recovered. There was no visible external evidence of burning, arcing, or heat distress in any of the wires removed. Several areas of wire insulation damage were found.

Thirty five wires were identified that could provide a possible short circuit path that could drive the latch actuator open with or without failures of other door electrical components if the ground handling bus was energized. The wires were schematically coded by function. Wires coded (-.-.-.-) were denoted for wiring that provides open command logic to the latch actuator. Wires coded (--.-.-) were denoted for additional wiring enabled by an activated (failed) S2 switch. Wires coded (-o-o-o-o) were denoted for wiring providing 28VDC power from the C285 circuit.

Potential short circuit paths were identified for the cargo door that could provide 28VDC to the latch actuator control circuit relay. These potential short circuit paths can cause the latch actuator to drive the latches toward their open position if 115VAC power is available to the latch actuator motor. The potential short circuit paths include two bare wires shorting against each other, bare wire-to-metal structure-to-bare wire contact, wire to conductive fluid (such as water) to wire, or a

combination of the aforementioned.

Conductive contact of (-o-o-o-o) or (---.---) coded wire with (-.---) coded wire could potentially result in providing a 28VDC circuit path to the latch actuator open circuit. Direct wire-to-wire paths are coded in Figure 17 as defined above. The two-wire short circuit paths are identified as wire pairs consisting of wire 101-20 shorting with any of the following wires; 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

If the S2 master latch lock switch fails in the "Not Locked" position, there are additional wire pairs that provide short circuit paths. These are coded in Figure 17 as (---.---) to (---.---) wire pairs.

Short Circuit Wire Damage Simulation Tests:

Tests were conducted by Boeing and United to simulate typical examples of bare wire short circuiting to determine the extent of visible wire damage that would be expected in the 28VDC cargo door control circuit.

United performed tests on BMS 13-42 wire, the wire type used in the B-747 cargo door control circuit. Visible electrical short circuit damage on bare BMS 13-42 wire surfaces was difficult to create at 28VDC. Surface damage was considered visible when detected by microscopic examination at 15X magnification. United testing simulated the relay coil resistance variations that would be found during typical in-service conditions. A current of 1.0 A at 28VDC created visible surface damage on momentary bare wire-to-bare wire contact. Multiple contacts at 1.0 A provided a more positive indication. A single momentary contact between two bare BMS 13-42 wires with 0.160 A at 28VDC did not create visible surface damage. Contact between a BMS 13-42 bare wire and Alclad 2024-T3 metal (airplane and cargo door structure) with 0.160A at 28VDC did not create visible surface damage.

Boeing performed wire tests on BMS 13-48 20 gauge wire. The test setup used the MS27418-2B door latch actuator control relay in parallel with the 60B00311-2 door restraint solenoid, the actual electrical loads used in the B-747 cargo door latch actuator control circuit. A single momentary contact of a bare 28VDC power wire, with a bare wire connecting to the relay of the solenoid, showed small pithead area developed at the point of wire contact that was visible without magnification.

Wire Examination Procedure:

All of the recovered wires were examined in the Safety Board's Materials Laboratory on a mylar sheet to simulate their installed positions. Labels were used to identify the coded wires using the manufacturer's original wire identification numbers imprinted on each wire's insulation. Wire pairs for direct electrical short circuiting were located in two common wire bundles installed on the cargo door. One common wire bundle was associated with the P3 plug connector, the other with the P4 plug junction box. The wire bundles were examined visually for areas of obvious insulation damage. Each individual wire was also examined with a stereo-microscope. Representative wire damage features were photographed.

Wire Damage Found:

Seven wires numbered 101-20, 102-20, 105-20, 107-20, 108-20, 122-20, and 135-20 had visible damage located near a 3.8 inch position as measured from the P3 plug pin tips. This common position on the wire corresponds to a 360-degree loop in the wire bundle, which is located immediately below the junction box. Figures 18 and 19 show typical wire damage. Wire 122-20 had an open insulation area approximately 0.25 inch long. The other four wires had flattened insulation damage areas.

In the P4 plug connector wire bundle, three wires displayed insulation damage. Wires 113-20, 121-20, and 124-20 had transverse insulation nicks, which exposed bare conductors. All three had insulation nicks 3 inches from the P4 plug pin tips; wires 121-20 and 124-20 had additional insulation nicks 34 inches from the plug pin tips. The two P4 insulation damage locations corresponded to wire bundle clamp positions.

1.16.3 Pressurization System

The pressure relief valves located on the left side of the fuselage in the forward cargo compartment

were removed from the airplane and subjected to bench tests at the UAL maintenance facility in San Francisco, California. No significant anomalies were discovered and both valves performed within specified tolerances.

1.16.4 General Inspection of Other UAL Airplanes

During the on-scene phase of the investigation, the Safety Board investigators examined six other B-747 airplanes while they were on the ground at HNL (four UAL airplanes and two operated by other carriers) to observe routine cargo door operations and to assess the condition of latching components. Generally, the door operations were normal. During the examination of latch pins on these airplanes, it was noted that most had a smooth wear ridge at the 9:00 position (looking forward) or were undamaged. All wear areas on the pins were smooth.

During electrical operation of the aft cargo door on one of the other UAL B-747 airplanes (N4718U), the pull-in hooks did not pull the door fully closed and the latch cams completed the closure. During operation of the latch cams, the bottom of the door moved, first circumferentially downward and then inboard. This additional movement was approximately 1/4 inch. A definite "thunking" noise was discernible as the door moved to its closed position at the end of cam rotation. On one occasion, the door would not open under electrical power. The door was "kicked" by a UAL mechanic, power was reapplied, and the door opened properly. Examination of the door by UAL mechanics, disclosed that the riveted plate holding the aft pull-in hook switch striker was loose.

All eight lower latch pins for the forward cargo door on N4718U exhibited a smooth ridge near the 9:00 position. Pins No. 1 and 2 also showed a smooth ridge at the 6:30 position with a smooth wear area between the 6:30 and 9:00 position. The forward and aft midspan cams of both forward and aft cargo doors had a heavy gouge mark corresponding to the end of the midspan latch pin.

N4718U was subsequently removed from service for repair of the aft cargo door latching mechanisms.

1.17 Additional Information

1.17.1 Previous Cargo Door Incident

On March 10, 1987, a Pan American Airways B-747-122, N740PA, operating as flight 125 from London to New York, experienced an incident involving the forward cargo door. According to Pan Am and Boeing officials who investigated this incident, the flightcrew experienced pressurization problems as the airplane was climbing through about 20,000 feet. The crew began a descent and the pressurization problem ceased about 15,000 feet. The crew began to climb again, but about 20,000 feet, the cabin altitude began to rise rapidly again. The flight returned to London.

When the airplane was examined on the ground, the forward cargo door was found open about 1 1/2 inches along the bottom with the latch cams unlatched and the master latch lock handle closed. The cockpit cargo door warning light was off.

According to the persons who examined the airplane, the cargo door had been closed manually and the manual master latch lock handle was stowed, in turn closing the pressure relief doors and extinguishing the cockpit cargo door warning light. Subsequent investigation on N740PA revealed that the latch lock sectors had been damaged and would not restrain the latch cams from being driven open electrically or manually. It was concluded by Boeing and Pan Am that the ground service person who closed the cargo door apparently had back-driven (opened) the latches manually after the door had been closed and locked. The damage to the sectors, and the absence of other mechanical or electrical failures supported this conclusion.

Further testing of the door components from N740PA and attempts to recreate the events that led to the door opening in flight revealed that the lock sectors, even in their damaged condition, prevented the master latch lock handle from being stowed, until the latch cams had been rotated to within 20 turns (using the manual 1/2 inch socket drive) of being fully closed. A full cycle, from closed to open, is about 95 turns with the manual drive system.

1.17.2 FAA Surveillance of UAL Maintenance

The Denver, Colorado, FAA Flight Standards District Office (FSDO) holds the operating certificate

for United Airlines, Inc. The FAA FSDO in San

Francisco, California, has the primary surveillance and oversight responsibility for UAL maintenance.

The FAA's PMI has the responsibility to oversee an airline's compliance with Federal Regulations with respect to maintenance, preventive maintenance, and alteration programs. The PMI determines the need for, and then establishes work programs for, surveillance and inspection of the airline to assure adherence to the applicable regulations. A portion of the PMI's position description reads as follows:

Provides guidance to the assigned air carrier in the development of required maintenance manuals and recordkeeping systems. Reviews and determines adequacy of manuals associated with the air carrier's maintenance programs and revisions thereto. Assures that manuals and revisions comply with regulatory requirements, prescribe safe practices, and furnish clear and specific instructions governing maintenance programs. Approves operations specifications and amendments thereto.

Determines if overhaul and inspection time limitations warrant revision.

Determines if the air carrier's training program meets the requirements of the FARs, is compatible with the maintenance program, is properly organized and effectively conducted, and results in trained and competent personnel.

Directs the inspection and surveillance of the air carrier's continuous airworthiness maintenance program. Monitors all phases of the air carrier's maintenance operation, including the following: maintenance, engineering, quality control, production control, training, and reliability programs.

At the Safety Board's public hearing on this accident, the PMI for United Airlines at the time of the flight 811 accident stated that he was trained as an FAA air carrier inspector and had been assigned to United Airlines since November 25, 1985. In addition to attending the normal FAA indoctrination course, he had received training in accident investigation, compliance enforcement, nondestructive testing, enforcement, and composite materials. To qualify for the position of PMI, he had completed a 3-week management training course at Lawton, Oklahoma. This was supplemented by a 2-week course on management training systems.

According to the PMI, FAA surveillance of UAL B-747 maintenance activities was organized around the daily work schedule of the FAA air safety inspector, specifically assigned to the UAL B-747 fleet by the PMI. The schedule for surveillance is normally prepared a year in advance by the FAA computerized Work Planning Management System (WPMS). Each FAA inspector is assigned specific responsibilities in the surveillance and monitoring of the airplane fleet to which he is assigned.

The PMI stated that assigned inspectors conducted surveillance of the UAL airplanes while they were in light or heavy maintenance and when they were released to service or in the process of preparing for a flight. Postflight surveillance was also performed. He said, as a routine, the inspectors visually inspected the airplanes and reviewed the airplane log records either during en route checks, while in flight, or upon termination of various flights. He said that inspectors conduct spot ramp inspections; however, they do not routinely observe ramp service operations as part of the surveillance program.

He said that FAA inspectors are not required to inspect the airplanes, but merely are to observe ramp service activities. Deficiencies or malfunctions were to be noted. The assigned inspector or the PMI would then report these observations to the UAL quality assurance liaison person or directly to UAL management.

The PMI stated that the FAA had conducted five special surveillance inspections of UAL in the previous 3 years and 5 months. The last special inspection, an MEL Survey Inspection, was completed in 1988. That inspection primarily addressed how many deferred maintenance items were being carried or deferred on each aircraft during a specified time period.

The PMI stated that his office does not approve the method by which the carrier complies with an AD, unless specified in the AD. However, a scheduled surveillance method was in place to review the carrier's AD compliance process and the ADs applicable to certain fleets. Each assigned

inspector had a schedule for performing this oversight in his work program. The PMI or his staff review a monthly report from the carrier listing ADs applicable to a particular fleet and their compliance. The FAA's surveillance of the carrier's AD compliance process involved a review of this list, not actual shop visits to verify compliance.

The inspector assigned to the UAL B-747 fleet stated that approximately 30 percent of his time was spent on actual ramp maintenance

surveillance. Other activities included: en route inspections, station inspections, meetings, classes and administrative paper work. Spot ramp inspections were scheduled as a normal routine, as well as by mandate in a particular AD.

The PMI stated that foreign contract maintenance bases were inspected once a year at a minimum. The PMI had the prerogative to use geographical surveillance inspectors (inspectors from other FAA offices), or inspectors from his office more familiar with UAL maintenance procedures to conduct inspections or investigations.

The PMI and the B-747 maintenance inspector assigned to UAL testified that, prior to this accident, they were not aware of any problems involving the operation of B-747 cargo doors, including the problems reported with N4713U during December 1988. The PMI testified that he could always use more inspectors to "conduct more in-depth surveillance and monitor UAL's fleet more adequately."

The extensive documentation of maintenance performed on UAL B-747 airplanes was forwarded to the PMI's official library by US mail. The data were ultimately channeled to the B-747 maintenance inspector. The PMI and maintenance inspector testified that the voluminous paperwork and work schedules precluded their monitoring the information to determine trends on problem areas.

1.17.3 Corrective Actions

On March 31, 1989, the FAA issued telegraphic (AD) ADT 89-05-54. This AD superseded AD 88-12-04 and required certain procedures to be accomplished when operating the cargo doors. These included: confidence checks of the door mechanical and electrical systems, inspections of the door locking mechanisms, and repairs if necessary. The AD also accelerated the schedule for terminating action to place steel doublers on the latch lock sectors, and it reinstated the procedures for using the eight view ports to verify the position of the latch cams, after the door is latched and locked.

The FAA, in conjunction with the Air Transport Association, the manufacturers, and other interested parties, are collectively working to address the human factor issues in the readability and understandability of ADs and SBs by line maintenance personnel. They are also reviewing the entire range of design, maintenance, and operation of outward opening doors to develop advisory information for pertinent parties.

FAA representatives stated at the Safety Board's public hearing that the FAA is increasing their operations and airworthiness inspector staffing by approximately 1,000 new hires in the next 3 fiscal years.

The PMI for UAL at the time of the accident stated at the Safety Board's public hearing that, as a result of the accident, "we have intensified our surveillance on the cargo door activities to the point where the assigned inspectors and inspectors who are not assigned to that particular fleet, 747s, are doing night surveillance, early morning surveillance, and we have intensified our surveillance on the cargo door in watching the operation of the cargo door to comply with the Airworthiness Directive."

On August 23, 1989, the Safety Board issued three safety recommendations (A-89-92 through -94) to the FAA. The recommendations urged the FAA to:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams.

Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the

actual position of both the latch cams and locks, independently.

Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions.

Section 4.0 contains the FAA's response to the recommendations and the status of the followup actions.

On October 12, 1989, the FAA issued NPRM 89-NM-148-AD, which proposed the amendment of ADT-89-05-54. The proposed revisions would require modification of the warning systems for the forward and aft cargo door, and the main deck cargo door, if installed. The modifications would provide visual

warnings to flightcrew and ground crew when the doors are not fully closed, the latch cams are not rotated to the closed position, or the lock sectors are not in the locked position. Further, the source for the warning signal would monitor the position of the latch cams. Public comments for the NPRM were due by December 27, 1989.

Boeing has completed tests that have verified the integrity of the upgraded latch lock sectors to prove that the latch cams cannot be back-driven through the lock sectors mechanically or electrically. Boeing also has been conducting tests on the B-747 cargo door to evaluate the effects of unrepaired damage and abuse on the latch/lock system. The tests, which determined the allowable damage limits on the latch lock system and mechanism support structures, were completed in March 1990. Additionally, Boeing conducted tests to evaluate any unlatching tendencies under cabin pressure loads. These tests were completed in November 1990 and included the measurement of loads in the latch system as the latch cams are rotated incrementally from the fully latched position to the unlatched position under pressurization loads.

The first series of tests included electrical backdriving of the latch cams into the lock sectors (both steel and steel reinforced were tested) with a modified latch actuator (the maximum output torque of the modified latch actuator was roughly twice that of a normal, torque-limiting latch actuator.) During these tests, the maximum cam rotation was 22.2 degrees against steel reinforced lock sectors and 18.8 degrees against the all-steel lock sectors.

During the second set of tests, which measured the effects of internal pressure loads on partially unlatched cams, it was discovered that pressurization did not create any significant loads in the latch mechanism with the door fully closed and the latch cams positioned up to 45 degrees from the fully latched position.

Both series of tests show that if the latch cams were somehow electrically backdriven by a latch actuator that had no torque-limiting ability, the steel or steel-reinforced lock sectors would limit the amount of cam rotation such that the partially unlatched cams would still prevent pressure loads from forcing the door open.

1.17.4 Boeing 747 Cargo Door Certification

Title 14 CFR 25.783, Amendment 25-15, effective October 24, 1967, was the original certification basis for Boeing 747 cargo doors. Specifically, Part 25.783(e) and (f) applied to doors for which the initial opening movement is outward (non-plug type doors). Those rules specified that:

(e) There must be a provision for direct visual inspection of the locking mechanism by crewmembers to determine whether external doors, for which the initial opening movement is outward (including passenger, crew, service, and cargo doors), are fully locked. In addition, there must be a visual means to signal to appropriate crewmembers when normally used external doors are closed and fully locked.

(f) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure.

Amendment 25-23, effective May 8, 1970, added the following text to paragraph (f): "...or failure of a single structural element." Amendment 25-23 did not apply to the initial certification basis for the B-747.

Amendment 25-54, effective October 14, 1980, expanded Part 25.783 (e), (f), and (g) to read:

(e) There must be a provision for direct visual inspection of the locking mechanism to determine if external doors, for which the initial opening movement is not inward (including passenger, crew, service and cargo doors), are fully closed and locked. The provision must be discernible under operational lighting conditions by appropriate crewmembers using a flashlight or equivalent lighting source. In addition, there must be a visual warning means to signal the appropriate flight crewmembers if any external door is not fully closed and locked. The means must be designed such that any failure or combination of failures that would result in an erroneous closed and locked

indication is improbable for doors for which the initial opening movement is not inward.

(f) External doors must have provisions to prevent the initiation of pressurization of the airplane to an unsafe level if the door is not fully closed and locked. In addition, it must be shown by safety analysis that inadvertent opening is extremely improbable.

(g) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure or failure of a single structural element.

At the Safety Board's public hearing, the FAA and the Boeing representatives acknowledged that during certification of the Boeing 747 the loss of a lower lobe cargo door was not considered to be an "acceptable event." Therefore, redundant mechanical devices and operational procedures were incorporated to protect against loss of the door in flight. Initial FAA certification approval of the Boeing cargo door design and operation included the installation and use of eight view ports on the door for ground personnel to observe the alignment of paint stripes on the latch cams with arrows on the latch pin support fitting, thereby complying with the requirements of 14 CFR 25.783(e), which require a ". . . provision for direct visual inspection of the door locking mechanism . . ." to determine if the door is closed and locked.

In correspondence dated November 24, 1969, and May 15, 1970, Boeing requested that the FAA approve the use of a visual inspection of the pressure relief doors of the cargo doors as an alternate method for determining the locked condition of the door. This design also provided a visual indication to the flightcrew via the cargo door warning light on the flight engineer's warning light annunciator panel. Boeing's request stated that this means of compliance "... provides a simpler check whereby only the pressure relief doors need to be checked . . ." by the ground crew, in lieu of actually observing the latch cams and alignment stripes through the eight view ports. Boeing also provided a Failure Analysis to support its request. The conclusion of the Failure Analysis reads: "Any failure, mechanical or electrical, within the latching system which results in open latches will always be indicated by open pressure relief doors." The FAA approved their alternate method on June 8, 1970. Subsequently, the procedures for maintaining the view ports and the alignment stripes in a serviceable condition,

which had been included in the UAL MM were removed. Also, the provision for observing the alignment stripes as part of the door closing procedure were not required for B-747 airline operators.

At the Safety Board's public hearing, a Boeing witness, in answer to a question relative to Boeing's possible consideration of modifications or design changes to the B-747 cargo door indication system to install a position switch directly on the latch cams, stated, "We are looking into the best possible designs that would provide indication on the cams and door closed, both exterior to the aircraft and in the flight deck. We are going to look into that.... However, we want to achieve the required indication in the most reliable method and we have not yet determined what that will be, or any changes (that) are necessary, or would make it more reliable than the way the system operates currently."

1.17.5 Advisory Circular AC 25.783-1

Advisory Circular (AC) 25.783-1 was issued December 10, 1986, on the subject, "Fuselage Doors, Hatches, and Exits." AC 25.783-1 set forth the acceptable means of compliance with the

provisions of Part 25 of the FAR's dealing with the certification of fuselage doors. Specifically, it provides for an acceptable method for showing compliance with the provisions of Part 25.783, Amendment 25-54.

Neither the provisions of Part 25.783, Amendment 25-54, nor the guidelines of AC 25.783-1 were part of the certification basis of the Boeing 747.

1.17.6 Uncommanded Cargo Door Opening--UAL B-747, JFK Airport

On June 13, 1991, UAL maintenance personnel were unable to electrically open the aft cargo door on a Boeing 747-222B, N152UA, at JFK Airport, Jamaica, New York. The airplane was one of two used exclusively on nonstop flights between Narita, Japan, and JFK. This particular airplane had accumulated 19,053 hours and 1,547 cycles at the time of the occurrence.

The airplane was being prepared for flight at the UAL maintenance hangar when an inspection of the circuit breaker panel revealed that the C-288 (aft cargo door) circuit breaker had popped. The circuit breaker, located in the electrical equipment bay just forward of the forward cargo compartment, was reset, and it popped again a few seconds later. A decision was made to defer further

work until the airplane was repositioned at the gate for the flight. The airplane was then taxied to the gate, and work on the door resumed.

The aft cargo door was cranked open manually, the C-288 circuit breaker was reset, and it stayed in place. The door was then closed electrically and cycled a couple of times without incident. With the door closed, one of the two "cannon plug" (multiple pin) connectors was removed from the J-4 junction box located on the upper portion of the interior of the door. The wiring bundle from the junction box to the fuselage was then manipulated while readings were taken on the cannon plug pins using a volt/ohmmeter. Fluctuations in electrical resistance were noted. When the plug was reattached to the J-4 junction box, the door began to open with no activation of the electrical door open switches. The C-288 circuit breaker was pulled, and the door operation ceased. When the circuit breaker was reset, the door continued to the full open position, and the lift actuator motor continued to run for several seconds until the circuit breaker was again pulled. At this time, a flexible conduit, which covered a portion of the wiring bundle, was slid along the bundle toward the J-4 junction box, revealing several wires with insulation breaches and damage.

UAL personnel notified the Safety Board of the occurrence, and the airplane was examined at JFK by representatives of the Safety Board, United Airlines, and Boeing. After the wires in the damaged area were electrically isolated, electrical operation of the door was normal when the door was unlocked. When the door was locked (master latch lock handle closed), activation of the door control switches had no effect on the door. This indicated that the S2 master latch lock switch was operating as expected (removing power from the door when it was locked). After the on-site examinations, the wiring bundle was cut from the airplane and taken to the Safety Board's materials laboratory for further examination.

The wiring bundle with the damaged wires contained all electric control wires (28 volt DC) and power wires (115 volt AC) that pass between the fuselage and the aft cargo door. From the forward side of the J-4 junction box, the bundle progresses in the forward direction, just above the forward pressure relief door, then upward, following the forward lift actuator arms. The bundle then enters an empty space between two floor beams, where the bundle has an approximate 180-degree bend when the door is closed. From this location, the wiring bundle progresses inboard, through a fore-to-aft intercostal between two floor beams. The wiring bundle then splits, with wires going in several directions.

The bundle is covered by the flexible conduit approximately from the lower end of the lift actuator arms to the fore-to-aft intercostal between the floor beams.

The conduit covering the wiring bundle is intended to prevent the wire bundle from being damaged during opening and closing of the door and during cargo handling operations. The conduit is a sealed flexible interconnector consisting of a convoluted helical brass innercore covered by a bronze braid. The innercore is soldered at every other convolute, and should be capable of

withstanding pressures exceeding 1,000 pounds per square inch (psi). Boeing has indicated that the conduit is an evolutionary improvement and that it has been installed on all B-747 airplanes produced since 1981 (from line number 489 on). Airplane N152UA was delivered in April 1987. Airplanes produced prior to 1981, including N4713U, used a bungee retraction system, to retract the cargo door wire bundle. Guidelines for the replacement of the bungee system with the flexible conduit were covered in Boeing Service Bulletin 747-752-2170, dated August 1981. The service bulletin was prompted by reports that the wire bundle bungee retraction system had not retracted the wire bundle sufficiently to prevent trapping the bundle between the cargo door and the door frame. UAL did not perform the retrofit on N4713U, which was line number 89, nor was the company required to do so.

Examination of the wires in the damaged area on the wiring bundle revealed that four of the wires were similar in appearance, with insulation breaches that progressed through to the underlying conductor. Adjacent to the breach on these four wires, the insulation was blackened, as if it had been burned. Another wire contained an extensive breach but no evidence of burned insulation. The damaged area was located on the bundle at a position approximately corresponding to a conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism. This support bracket was found bent in the forward direction. In addition, mechanical damage was noted on adjacent components in this area.

A second damaged area was noted on the wiring bundle at a position approximately corresponding to the conduit swivel clamp at the elbow between the two arms of the forward lift actuator mechanism. Wires in this area were missing portions of their exterior coating, but no breaches to the underlying conductors were noted.

The exterior braid on the conduit contained minor rub marks and was slightly kinked at a position corresponding to the area on the wires with breached insulation. Additional examinations revealed that the innercore of the conduit contained multiple circumferential cracks in the areas corresponding to the damage areas on the wires. The cracks were in the convoluted innercore directly adjacent to the inside diameter of the conduit.

The lock sectors, latch cams, and latch pins from the aft cargo door were examined on the incident airplane and were generally in excellent condition. There was no evidence to suggest that the cams had ever been electrically (or manually) driven into or through the lock sectors.

Boeing also informed the Safety Board that, in May of 1991, a B-747 operated by Qantas was found to have chafing of the wires in the wire bundle to the aft cargo door. This airplane also had a flexible conduit protecting the wires, and the chafing was located approximately at the standoff pin on the bracket at the upper arm of the forward lift actuator.

The Safety Board determined that the chafing of the wires on the airplane involved in the JFK occurrence was caused by, or was greatly accelerated by, the circumferential cracks in the conduit and that the cracks in the conduit were caused either by repeated flexing of the conduit as the cargo door opens and shuts or by unusual stresses on the conduit generated concurrently with damage to the conduit guide bracket and attached standoff pin on the upper end of the forward lift actuator upper arm.

A portion of the wire bundle for the forward cargo door on many B-747 airplanes is also covered by a flexible conduit that is very similar to the conduit for the aft cargo door. However, there are substantial differences between the orientation of the flexible conduits for the two doors, and the Safety Board has not become aware of problems associated with the flexible conduit for the forward door.

Nevertheless, because of the concerns about the chafed wires and possible electrical short circuits, on August 28, 1991, the Safety Board recommended that the FAA:

Issue an Airworthiness Directive applicable to all Boeing 747 airplanes with a flexible conduit protecting the wiring bundle between the fuselage and aft cargo door to require an expedited inspection of:

- (1) the wiring bundle in the area normally covered by the conduit for the presence of damaged

insulation (using either an electrical test method or visual examination);

(2) the conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism;

(3) the flexible conduit for the presence of cracking in the convoluted innercore.

Wires with damaged insulation should be repaired before further service. Damage to the flexible conduit, conduit support bracket and standoff pin should result in an immediate replacement of the conduit as well as the damaged parts. The inspection should be repeated at an appropriate cyclic interval. (Class II, Priority Action) (A-91-83)

Evaluate the design, installation, and operation of the forward cargo door flexible conduits on Boeing 747 airplanes so equipped and issue, if warranted, an Airworthiness Directive for inspection and repair of the flexible conduit and underlying wiring bundle, similar to the provisions recommended in A-91-83. (Class II, Priority Action) (A-91-84)

The FAA responded to these safety recommendations on November 1, 1991, stating that it agreed with the intent of the recommendations and that the issuance of an NPRM was being considered to address the issues in the safety recommendations. The Safety Board replied on November 27, 1991, classifying each of the recommendations as "Open--Acceptable Response," pending the completion of the rulemaking process. Since that exchange of correspondence, the FAA has published an NPRM which is now being reviewed by the Safety Board. Safety Recommendations A-91-83 and -84 will continue to be classified as "Open--Acceptable Response" until an acceptable final rule is published.

2. ANALYSIS

2.1 General

This analysis is based on the facts gathered during the initial investigation phase, without the benefit of the evidence from the cargo door, updated to include the findings from the subsequent examinations of the door after it was recovered.

The flightcrew and flight attendants were trained and qualified in accordance with the applicable Federal regulations and UAL standards and requirements. There were no air traffic control or weather factors related to the cause of this accident.

The airplane had been properly maintained, with the exception of certain requirements pertaining to the cargo doors. Those discrepancies will be discussed in detail in this analysis.

The evidence examined by the Safety Board during its investigation revealed conclusively that this accident was precipitated by the sudden loss of the forward lower lobe cargo door, which led to an explosive decompression. There was no evidence of preexisting metal fatigue or corrosion in the structure surrounding the cargo door. All breaks were the result of overload at the time of the loss of the door. There was no evidence of a bomb or similar device that caused an explosion on the airplane.

The explosive decompression of the cabin when the cargo door separated caused the nine fatalities. The floor structure and seats where the nine fatally injured passengers had been seated were subjected to the destructive forces of the decompression and the passengers were lost through the hole in the fuselage. Their remains were not recovered. Most of the injuries sustained by the survivors were caused by the events associated with the decompression, such as baro-trauma to ears, and cuts and abrasions from the flying debris in the cabin. Other injuries were incurred during the emergency evacuation.

The loss of power to the Nos. 3 and 4 engines was caused by foreign object damage when debris were ejected from the cargo compartment and cabin during the explosive decompression. The debris also caused damage to the right wing leading edge flap pneumatic ducting, and other areas along the right side and empennage of the airplane.

During the approach to HNL, all of the leading edge flaps had extended, except the outboard sections 22 through 26 on the right wing. The reason that they failed to extend probably was the damage to the pneumatic duct caused by the ejected debris. The pneumatic pressure probably was too low to actuate the most outboard flaps to the extended position.

The failure of the flightcrew and passenger oxygen systems was caused by structural deformation and damage to the supply lines in the area adjacent to the cargo door and failed fuselage structure.

The Safety Board's analysis of this accident concentrated on the reasons for the loss of the cargo door and the events that led to its loss in flight. The analysis included an evaluation of the design, certification, and approval processes for the B-747 cargo doors, and the operational, maintenance, and inspection processes for the doors. Also, the analysis included an evaluation of the historical events that had occurred over the past months and years that eventually led to this accident.

2.2 Loss of the Cargo Door

The calculated pressure differential at the time of the loss was about 6.5 psi, which would have exerted a load on a properly closed and locked door that was substantial, but well within design limits.

There was no evidence of a structural problem with the cargo door that could have caused it to fail from metal fatigue or corrosion. Although the cargo door was recovered in two pieces on the floor of the ocean, there was no evidence of a pre-separation structural failure of the door. All fractures and damage found on the door were determined to be the result of the sudden opening of the door rather than the cause. The evidence showed that the door was intact when it flew open violently and that its integrity was compromised when it struck the upper fuselage structure and most likely when it struck the water. The fracture in the cargo door occurred just below the midspan latch cams. Paint marks on the outer surface of the door that matched upper fuselage structure paint pattern, damage to the latch pins, pull-in hooks and hook pins, as well as damage to the floor structure near the upper door hinge area were consistent evidence that the door was intact when it flew open.

The evidence was also conclusive that the failure of the door did not result from the failure of the structure surrounding the door. The damage to the cabin floor beam structure, adjacent to the cargo door hinge area, showed that decompression loads in the cabin broke the beams downward when pressure was released from the cargo compartment. The fuselage skin above the door was torn away during the decompression as the door separated violently from the airplane. Unfortunately, the upper skin structure was not recovered from the sea.

There are no reasonable means by which the door could open in flight with the cams properly closed and locked. If the lock sectors were in proper condition, and were properly situated over the closed latch cams, the lock sectors had sufficient strength to prevent the cams from vibrating to the open position during ground operation and flight. Thus, the only ways in which the cargo door could open while in flight involve the placement of the cams in a partially latched or unlatched position. Either the latching mechanisms were forced open electrically through the lock sectors after the door was secured, or the door was not properly latched and locked before departure. Then the door opened when the pressurization loads reached a point at which the latches could not hold.

2.3 Partially Closed Door

Examination of the eight latch pins that had been removed from the lower sill of the forward cargo door revealed smooth wear patterns where the latch cams had normally rotated around the pins. These wear patterns indicate that interference had existed during normal operation between the cams and the pins over an extended period of time. All eight pins also had roughened areas from approximately the 6:15 position to the 7:30 position (clock references are as looking forward, 9:00 being directly inboard). The 7:30 position corresponds closely to the area where the lower surface of the cam first contacts the pin as the door reaches the nearly closed position, before the cams are rotated to the latched position.

The hoop stresses generated by pressurization of the airplane create a bearing load against the cam/pin contacting points. Even if the cams are in the unlatched position, and the airplane is pressurized, this bearing load could act as a frictional latch between the cams and the pins and would tend to keep the door in the closed position.

Transferred cam material and heat tinting of the pin surface was found to extend from the point where the cam-to-pin interface at the near fully open position of the latch cams (7:30 position) to a

position corresponding to the bottom of the pin (6:15 position). This evidence was found on the roughened areas on all of the pins. The heat tinting and metal transfer are indicative of the high stress and rapid movement of the cam across the pin when the door separation occurred. Therefore, the location of this evidence indicates the probable location of the cams just before, and at the time of, separation of the door. The Safety Board concludes that these markings and their location on the pins resulted from a very fast, high bearing stress, separation of the cams across the pins, when the cams were in or very close to the unlatched position. Further, examination of the recovered cargo door confirmed that the latch cams were in a nearly unlatched position at the time the separation occurred. The lock sectors were found in the locked position jammed against the cams. Therefore, the cargo door latch cams had been closed, the master latch lock handle had been closed, and the lock sectors had moved to the locked position. Subsequently, the cams had been back-driven to the near-open position, deforming the lock sectors.

The pull-in hooks and pull-in hook pins would also counteract the pressurization loads in the outward direction, providing that the latch cams were not engaged on the latch pins and carrying the pressurization loads. However, Boeing studies showed that the pull-in hooks would fail at a pressure differential of about 3.5 psi, assuming that the cams are in the unlatched position and that there is no bearing load on the pins. Therefore, based on the probable pressure differential of about 6.5 psi just before the door separated, it is concluded that forces other than the pull-in hooks/pins were holding the door closed. Since the flightcrew and passengers reported no pressurization difficulties until the explosive decompression, it is reasonable to conclude that the door was being held closed by the bearing stresses of the cam-to-pin interfaces as well as by the pull-in hooks.

The Safety Board believes that the approximate 1.5 to 2.0 seconds between the first sound (a thump) and the second very loud noise recorded on the CVR at the time of the door separation was probably the time difference between the initial failure of the latches at the bottom of the door, and the subsequent separation of the door, explosive decompression, and destruction of the cabin floor and fuselage structure. The door did not fail and separate instantaneously; rather, it first opened at the bottom and then flew open violently. As the door separated, it tore away the hinge and surrounding structure as the pressure in the cabin forced the floor beams downward in the area of the door to equalize with the loss of pressure in the cargo compartment.

Three possible theories to explain why the latch cams could have been in a partially latched condition during flight are examined: (1) they were never closed fully before the door was "locked" before takeoff. (2) they were backdriven manually after the door had been fully latched and locked or (3) they were back-driven electrically after the door had been fully latched and locked.

2.4 Incomplete Latching of the Door During Closure

The Safety Board considered the possibility that the master latch lock handle had not been closed before the airplane departed the gate, and the possibility that the shrouds recommended by SB-747-52-2097 for the cargo door pressure relief doors were not installed on the forward door. If this were the case, it is possible that this condition allowed the pressure relief doors to be rotated closed when the airplane pressurized.

The Safety Board believes that these events were very unlikely based on the statements of the ramp personnel, line maintenance personnel, and the flightcrew. The ramp and maintenance personnel would have to have missed seeing the master latch lock handle in the unstowed position and the pressure relief doors open before departure. Also, the flightcrew would have to have missed seeing the cockpit cargo door warning light indication.

The examination of the recovered forward cargo door did not provide confirmation that the pressure relief door shrouds were actually installed on the forward door, although UAL records showed that they had been installed on both cargo doors of N4713U, in accordance with SB-747-52-2097. However, the shrouds were found not to be installed on the aft door, contrary to UAL records, and therefore may not have been installed on the forward door. Without the shrouds, the pressure relief doors could have rotated shut during the pressurization cycle. Because the closure of the pressure relief doors would back-drive the lock sectors, this scenario would presume

previous damage to the sectors, which would permit the sectors to move over the unlatched cams. Before recovery of the cargo door, the Safety Board believed that the lock sectors might have been damaged some time prior to the accident flight to the extent that they could have been moved to the locked position even though the latching cams were not fully closed.

During closure of the door, the latch actuator may not be able to rotate the cams to the fully closed position because of excessive binding forces between the latch cams and pins. This could occur if the cargo door is misaligned (out of rig) or if the pull-in hooks do not pull the door in far enough to properly engage the cams around the pins. There is sufficient evidence of wear on the pins and from the previous discrepancies with the door to indicate that the door was misaligned and not properly rigged.

The smooth wear areas found on the pins from N4713U are signs of heavy contact (interference) between the cams and pins during numerous past closings and openings of the door. This wear, other evidence from the door, and the maintenance history of the door, suggest strongly that the door was out of rig during the weeks and months before the accident.

The wear pattern damage to the pull-in hook pins also showed interference during the normal ground operations prior to the accident. This is further evidence of an out-of-rig door. It is also possible that the excessive binding force acting over a period of time precipitated a failure of the latch actuator. Regardless of the reason(s), the conditions of the latch pins and pull-in hook pins showed prolonged out-of-rig operation.

Most of the previous discrepancies with the forward cargo door on N4713U during December 1988 involved problems with closing the door electrically. These problems always occurred when the airplane was fully or nearly fully loaded, just before departure. The trouble-shooting and corrective actions by UAL maintenance, which on some occasions only involved cycling the door and finding it functional, were performed when the airplane was not fully loaded, during overnight maintenance inspections. The flexing of the fuselage with a full load of fuel, cargo, and passengers could have caused distortion of the door frame and resulted in misalignment between the cams and pins. In this case, the pull-in hooks may not have pulled the door fully in before the cam actuator attempted to latch the door. The wear evidence on the latch pins from N4713U suggests that this event had been occurring before the accident.

Safety Board investigators also witnessed this event during inspection and operation of the aft door on another UAL B-747, N4718U, in HNL. It was noted that the door on N4718U was not being pulled in fully by the pull-in hooks, so the latch cams completed the closing cycle with significant interference and "thunking" sounds. In fact, the out-of-rig door on N4718U failed to operate electrically at one point during its examination.

By design, any attempt to close the master latch lock handle and move undamaged lock sectors into place would not be successful unless the cams were rotated to near the fully latched position. This condition was substantiated by Boeing tests. Even with severely damaged lock sectors, as found on the Pan Am B-747, if the cams were more than 20 turns from the fully closed position on the Pan Am airplane, the master latch lock handle could not be stowed. Examination of the recovered N4713U door indicated that the door lock sectors were generally intact and jammed against the cams that had been back-driven into the lock sectors. Consequently, if the latch cams had been in the nearly unlatched position as found on the recovered door at the time the cargo handler attempted to move the master latch lock handle, the interference between the cams and the lock sectors would have prevented the master latch lock handle from moving to the closed position. Furthermore, this interference would have prevented the closure of the pressure relief doors as the airplane pressurized, irrespective of the possible absence of the pressure relief door shrouds. This conclusion is supported by extensive testing of the latch/lock mechanisms following the recovery of the door.

Therefore, based upon the examination of the lock sectors and the tests that were conducted, the Safety Board concludes that the latches were fully closed and that the locking handle was placed in the stowed position after the cargo was loaded.

2.5 Manual Unlatching of the Door Following Closure

It is possible that the cams could have been manually back-driven (about 95 turns) after the door had been secured; however, the UAL ramp personnel involved with dispatching the flight stated that the door was operated electrically. Furthermore, it seems unlikely that the ramp personnel would have driven the manual latch actuator 95 turns toward the open position after the door was fully latched.

The placard/seal located over the latch actuator manual drive on the recovered door was found with damage that initially suggested it had been previously compromised. If this were the case, it would indicate that someone may have used the manual drive to operate the door latches on an earlier flight or possibly immediately before the accident flight. However, the Safety Board believes that an insertion of a screw driver and rotation of the plate retaining screw would have caused rotational tearing around the circumference of the screw head. There was no such tear. Rather, the damage to the placard/seal was more consistent with that which would occur from impact and underwater pressure

forces. Therefore, the evidence strongly suggests that manual operation of the latch actuator by ground service personnel after the door was properly closed is unlikely.

2.6 Electrical Unlatching of the Door Following Closure

2.6.1 Conditions or Malfunctions Required to Support Hypothesis

It was determined in 1987, after the Pan Am incident, that the locking sectors for B-747's, including those installed on N4713U, could be overcome by the force of the latch cam actuator, electrically or mechanically. If the latch cam actuator had been energized for some reason with the originally designed unstrengthened lock sectors installed, the latch actuator motor was capable of driving the latch cams open through properly positioned lock sectors, whether they were damaged or undamaged. Therefore, the locking sectors installed as original equipment for B-747's, and those installed on N4713U, would not perform the locking function as intended by the design. They would not "lock" the latches in place as implied by the name "lock sectors."

The investigation has shown that there are several conditions that must be met before the latch actuator will electrically drive the latch cams to the unlatched position on the B-747 after the door has been properly closed and locked. First, the ground handling power bus must be energized by having external power connected, or the APU must be operating and the APU generator field switch in the cockpit must be set to power the bus via the No. 2 ground handling power relay. Second, the air/ground relay must be in the "airplane on the ground" position. These two conditions are normally present when the airplane is on the ground before engine startup. Third, there must be a signal to the door open position in one of the two door open/close switches. Fourth, the S2 master latch lock switch, which cuts off power to the door actuators when the handle is stowed, must sense "not locked."

Therefore, it would take several independent conditions and some failures to provide for electrical power to be available to drive the door open electrically once it is closed and locked. The number of conditions and combinations depend upon the phase of operation of the airplane.

While the airplane was on the ground, before engine startup, with the master latch lock handle stowed, the external power connected (or with the APU running), and the ground handling bus powered, an "open" signal to the cargo door

latch actuator would have occurred if any of the following combinations of conditions had been met: (1) a malfunction of the S2 master latch lock switch and the placement by someone of one of the door control switches to the "open" position; (2) a malfunction of the S2 master latch lock switch and certain short circuits; or (3) a two-wire short circuit path consisting of wire 101-20 shorting with any of the following wires: 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

While the airplane was on the ground, after engine startup, and with the cargo door master latch lock handle stowed and the APU running, an "open" signal to the door latch actuator would have occurred if the following conditions had been met: (1) an energized ground handling bus resulting from the flightcrew reenergizing the APU generator field or failure of the No. 2 ground handling

power relay; (2) a malfunction of the S2 master latch lock switch; (3) a malfunction of either of the door open/close switches or the placement of the switch in the "open" position by someone. An "open" signal would have also occurred had certain wire short circuits been present with condition (1) alone, or with conditions (1) and (2).

Regardless of the cause, electrical power to the latch actuator would have had to persist for the time necessary to rotate the cams to the nearly open position. If the electrical power had been applied for a longer time, the latch cams could have opened fully and caused the pull-in hooks to rotate open, a situation that would have prevented the airplane from pressurizing after takeoff. However, it is also possible that the latch actuator stalled before they opened fully because of the forces of the interference between the lock sectors and the cams as they were back-driven.

After takeoff, electrical operation of the door latch actuator would have required: (1) the APU to be running; (2) malfunction of the air/ground relay, (3) malfunction of the No. 2 ground handling power relay; and (4) malfunction of the S2 master latch lock switch and one of the cargo door open/close switches or a short circuit of the aforementioned wire pairs. Although the flightcrew could conceivably energize the ground handling bus from the APU by actuating the APU generator "field" switch, there was no evidence that they did so.

Thus, regardless of the phase of operation, either a wiring short circuit or a failure of the S2 master latch lock switch combined with some other anomaly or action would be required to cause the latches to move toward the open position. Before the recovery of the door, the Safety Board was able to examine two of the electrical relays and the door open/close switches from N4713U that would have to have failed to allow electrical operation of the cargo door in flight, with the APU

running. These were the No. 2 ground handling power relay, the air/ground relay, and the internal and external door open/close switches. The examination of the relays and switches revealed no evidence of a single fault or conditions that might have caused an intermittent failure mode. The arcing noted on the No. 5 terminal of the outside door control switch was on the door "close" circuit and could not have been related to a short to the open mode. Further, because the flightcrew did not note a cargo door warning light, and the fact that the airplane was able to be pressurized, confirms that the master latch lock handle was in the closed position before takeoff. This position would actuate the master latch lock switch to disconnect power to the door opening actuators.

According to the flightcrew testimony and the pilots' comments recorded on the CVR during the flight, the APU was shut down shortly after takeoff and remained in that condition. Engine generators cannot power the ground handling bus from which the cargo door actuating mechanisms are powered. Once the APU was shut down, there was no power available to any of the cargo door electrical components. Therefore, an electrical actuation of the latch cam actuator at the time of the door loss was not possible.

The Safety Board believes that there is another reason why the opening of the door could not have been caused by electrical actuation shortly before the explosive decompression. Because the door carries the structural loads (hoop stresses) through its hinge and latches, the latch cams would be heavily loaded against the latch pins when the airplane was pressurized to the 6.5 psi differential pressure that was calculated to have been present at the time of the decompression. In that case, the torque limiter within the actuator would probably slip well before the actuator could achieve the torque necessary to drive the cams open against the frictional lock produced by the high bearing stresses resulting from pressurization.

2.6.2 Electrical Switches and Wiring Examinations--Recovered Door

All cargo door position sensing switches (S2 through S9) were found installed in their proper position. The cargo door recovery team found the S2 master latch lock switch in the "not-locked" position immediately after the door was aboard the recovery ship. This position would be consistent with the master latch lock handle being open. Further tests of the S2 switch revealed damage that probably resulted from the pressures under the sea. The only notable exception was a broken internal bracket that may have affected the operation of the switch prior to the accident. Other similar switches did not exhibit this failure. It is

therefore possible that the S2 master latch lock switch failed prior to the accident, allowing more possibilities for electrical short circuits to power the latch actuator. Nevertheless, despite extensive testing, it could not be determined whether the S2 switch was functional before the accident.

The examination of 35 wires that remained with the recovered cargo door revealed several areas of damaged insulation that could have permitted an electrical short circuit to power the latch actuator. However, no evidence was noted of arcing that was indicative of short circuits. Furthermore, a significant number of the wires that had the potential for allowing for short circuits to power the latch actuator were not recovered. Testing conducted by Boeing and by UAL was inconclusive regarding whether a short circuit would have left detectable evidence of arcing. Therefore, the Safety Board was unable to determine whether the latch actuator was inadvertently powered by a short circuit in the cargo door wires.

The incident involving a UAL Boeing 747 at JFK Airport on June 13, 1991, confirmed that electrical short circuits in the cargo door wiring could cause the door to open. In this case, the short circuits were in the fuselage-to-cargo door wiring bundle where the bundle was covered by a flexible conduit. Although N4713U did not have a flexible conduit installed at the forward door position, its wiring was routed over the top of the door hinge where exposure to damage could occur. That portion of the wiring from N4713U was not recovered from the sea. The wires located at the door hinge area are more susceptible to in-service damage from movement during the open/close cycle, as compared with the wires mounted on the door that are normally static.

Following the incident at JFK, UAL directed that the circuit breaker that terminates power to the cargo doors be pulled after the door is closed and before departure of every B-747 flight. UAL obtained approval for this practice from the FAA and requested Boeing and the FAA to make such a practice part of the approved manual for the airplane. Neither Boeing nor the FAA acted on UAL's request.

Nevertheless, the Safety Board believes that the FAA should initiate rulemaking to include design considerations for nonplug transport category aircraft cargo doors that would deactivate the electrical circuitry to the door actuators after the doors are closed and locked. The catastrophic nature of the loss of a cargo door dictates the need to provide additional redundancies and fail-safe features in the door mechanisms to supplement the hardware safety features.

2.6.3 Possibility of Electrical Malfunction

Due to the lack of physical evidence, the Safety Board was unable to conclude that an electrical short caused the cargo door actuator to move the latch cams to the nearly open position, allowing the door to separate when the cabin pressure exceeded the load-carrying capability of the door latches. Neither could this possibility be eliminated. A momentary actuation of the door open switch by someone on the ground in the presence of a faulty S2 switch could also have caused the latches to open through the closed lock sectors. However, no evidence has been found that someone actuated the switch after the door was initially closed and locked.

The Safety Board concludes that it was not possible for the cargo door to have opened electrically at the time of the loss of the door. There was no power to the ground handling bus to power the actuator, even if there had been an electrical short. Further, the Safety Board concludes that it is highly improbable that an electrical short could have caused the latches to open after the airplane was airborne. Although the ground handling bus could conceivably have been powered, failures of other components that were tested as functional would also have been necessary.

The Safety Board believes that the electrical operation of the latch actuators from the fully closed and locked position most likely occurred before the engines were started when the ground handling bus was powered. The precise source of the electrical actuation could not be determined. Once the engines were started, the possibility of an electrical short decreases significantly because the ground handling bus is disengaged from the APU when the engines start. There was no evidence that the flightcrew reengaged the ground handling bus.

Because the preaccident condition of the S2 master latch lock switch could not be determined, it could also not be determined whether its proper functioning would have prevented the accident.

The Safety Board did not determine whether damaged cargo door wires or a malfunctioning S2 switch could have been found by UAL maintenance had they been more aggressive in troubleshooting the cargo door problem in the weeks prior to the accident.

2.7 Design, Certification, and Continuing Airworthiness Issues

The Safety Board's analysis of this accident went beyond the conclusions about how the door failed. The Safety Board also examined the initial

design and certification of the B-747 cargo door, and the continuing airworthiness system that should have prevented this accident, to identify the breakdowns in this system that led to the accident. As is the case with most aviation accidents, there are many factors that led up to the actual failure of the door on flight 811.

The Safety Board found that there were multiple opportunities during the design, certification, operation, and maintenance of the forward cargo door for N4713U for persons to have taken actions that could have precluded the accident involving flight 811. The circumstances that led to this accident exemplify the need for human factors considerations in the promulgation of regulations, the application of regulatory policies, the design of airplane systems, and the quality of airline operational and maintenance practices.

The first opportunity to prevent this accident occurred during the design and certification of the B-747 cargo door mechanical systems, when the design was chosen and approved, which allowed for the overriding of the lock sectors by either mechanical or electrical actuation. It is apparent that the original design was not tested sufficiently to verify that the locking sectors in fact "locked" the latch cams in the closed position. This shortcoming should have become apparent during the initial certification testing and approval process. Later, it should have become apparent when Boeing applied for, and the FAA granted, an alternative method of compliance with the certification regulations (25.783 [e]) that permitted the elimination of operational practices that included a visual verification of the cargo door latch positions via view ports in the doors.

The failure mode analysis performed by Boeing, and the FAA's acceptance of its content in granting the exemption, probably were based on the assumption that the lock sectors would always prevent the master latch lock handle from being in a stowed position when the latch cams were not fully closed. This assumption was not valid, as evidenced by the findings in 1987 following the Pan Am incident that the lock sectors could not prevent the latch cams from being driven from the fully latched position with the master latch lock handle stowed, while a false indication was provided to the flightcrew that the cargo door was properly latched and locked. At the time that Boeing sought approval of the alternative compliance, Boeing and the FAA should have reviewed the design and required testing of the door latch/lock mechanisms to verify their integrity. Thus, the procedure for direct viewing of the latches via the view ports before the airplane could be dispatched should not have been eliminated without adequate verification that the lock sectors were totally effective.

The next opportunity for the FAA and Boeing to have reexamined the original assumptions and conclusions about the B-747 cargo door design and certification was after the findings of the Turkish Airline DC-10 accident in 1974 near Paris, France. The concerns for the DC-10 cargo door latch/lock mechanisms and the human and mechanical failures, singularly and in combination, that led to that accident, should have prompted a review of the B-747 cargo door's continuing airworthiness. In the Turkish Airlines case, a single failure by a ramp service agent, who closed the door, in combination with a poorly designed latch/lock system, led to a catastrophic accident. The revisions to the DC-10 cargo door mechanisms mandated after that accident apparently were not examined and carried over to the design of the B-747 cargo doors.

Specifically, the mechanical retrofit of more positive locking mechanisms on the DC-10 cargo door to preclude an erroneous locked indication to the flightcrew, and the incorporation of redundant sensors to show the position of the latches/locks, were not required to be retrofitted at that time for the B-747. Of similar concern is the fact that the cargo doors for the L-1011 required redundant latch/lock indication sensors at initial certification, during the approximate same time frame the DC-

10 and B-747 were certificated.

More recently, when Boeing and the FAA learned about the circumstances of the Pan Am cargo door opening incident in March 1987, more timely and positive corrective actions should have been taken. The Safety Board believes that the findings of that incident investigation should have called into question the assumptions and conclusions about the original design and certification of the B-747 cargo door, especially the alternative method for verifying that the door was latched and locked that was sought by Boeing and was granted by the FAA. Since a B-747 cargo door opening in flight was considered to be an "unacceptable event", once a door did come open in flight, the FAA and Boeing should have acted much quicker to prevent another failure.

It took nearly 16 months from the date of the Pan Am Incident (March 10, 1987) until the FAA issued AD-88-12-04 (July 1, 1988). And then, the AD allowed 18 or 24 months, depending on the model B-747, from the date of its issuance for compliance with the terminating actions of the AD. The fact that Boeing had issued an Alert SB as a result of the Pan Am incident is an indication of the apparent urgency with which Boeing treated this issue. Alert SB's are issued for "safety of flight" reasons, while regular SB's deal with "reliability" and not necessarily safety of flight items. Despite this, the terminating action, issued as

revision 3 to the Alert SB, on August 27, 1987, was not mandated by the FAA for 11 months.

The Safety Board found no evidence that the FAA or Boeing reassessed the original design and certification conclusions regarding the safety of the B-747 cargo door during this period. Several opportunities for preventive action were also missed by UAL during this period. First, UAL delayed the completion of the terminating actions of Alert SB 52A2206 (Rev 3 and AD-88-12-04). In fact, there was no evidence that UAL had intended to comply with the terminating action of the Alert SB, until it was mandated by the FAA.

It is understandable that an airline would not take its aircraft out of service to incorporate revisions that do not appear to be safety critical. Although by definition an Alert SB is safety related, there was no implication from Boeing's and FAA's actions regarding this matter that urgency was required. The airlines rely on the airframe manufacturers and the FAA to evaluate the need for urgent airworthiness actions that might take airplanes out of revenue service. In this case, UAL had scheduled completion of its B-747 fleet modifications in accordance with the terminating actions for AD-88-12-04 before the final allowable date; however, the schedule was based on other heavy maintenance schedules to prevent unnecessary down-time of its airplanes.

UAL personnel stated after the UAL 811 accident that its personnel did not fully appreciate the importance, or safety implications, of the terminating actions, or they would have incorporated the improvements much earlier. The usual difficulties in setting short suspense dates for performing terminating actions in AD's, such as parts availability, did not seem to exist in this case, because the parts were not complex components and probably could have been fabricated fairly quickly in-house by most airlines.

Human performance certainly contributed to UAL's failure to incorporate an important inspection step into its maintenance program as mandated by AD-88-12-04. When UAL obtained an advance draft copy of the forthcoming NPRM that eventually led to the AD, the airline began preparing its work orders to implement the forthcoming the AD requirements into its B-747 fleet (30 airplanes at the time). UAL developed its maintenance work sheets from the text of the draft NPRM, which was virtually identical to the text of the final rule. As a result of a clerical error, one of the important inspection steps required by the AD was omitted.

Apparently, UAL maintenance personnel never compared the work sheets they received with the actual requirements of the AD, or if they did, the omission was not detected. FAA inspectors responsible for oversight of UAL's maintenance program also did not detect this error because normal surveillance of AD compliance merely involved verifying the correctness of UAL's paperwork that listed the applicable AD's and compliance dates. The inspectors did not actually verify UAL's compliance action by shop visits, or by comparison of work sheets with AD provisions. These omissions by the UAL maintenance and quality assurance personnel, and the

limitations of the FAA surveillance procedures were probably significant in setting the stage for the events that led to the actual cause of the door separation from N4713U.

Another matter of concern is the quality of UAL's trend analysis program. There was no indication that the repeated discrepancies with the forward cargo door on N4713U "raised a flag" within the UAL maintenance department. A quality assurance or trend analysis program should have detected an adverse trend and should have prompted efforts to resolve the repeated problems. If it had, any faults in the door electrical system or damage to mechanical components might have been detected. In summary, the Safety Board concludes that there were several opportunities wherein Boeing, the FAA, and UAL could have taken action during the initial design and certification of the B-747 cargo door, as well as during the operation and maintenance of the cargo door installed on N4713U, to ensure the continuing airworthiness of the cargo door. The Safety Board further concludes that these deficiencies and oversights contributed to the cause of this accident.

2.8 Survival Aspects

The Hickam ARFF units and the airport's ARFF units operated on separate radio networks and thus they could not communicate directly on-scene by radio. This situation required them to communicate by voice. Although the two ARFF services had a common radio frequency (as per the Airport Emergency Plan), procedures for its use had not yet been developed. The Safety Board believes that such communication procedures should be expeditiously developed.

The use of camouflage paint schemes on military ARFF vehicles may be appropriate for military purposes; however, the Safety Board believes that camouflage is not appropriate for ARFF vehicles that are operated at a joint-use airport. It is obvious that these vehicles must be conspicuous to be seen by other

responding vehicles and by persons who are involved in the accident, such as airport and airline personnel, crew and passengers, and off-airport firefighting and rescue vehicles.

The National Fire Protection Association Standards recommend for primary firefighting, rapid intervention and combined agent vehicles, that, "Paint finish shall be selected for maximum visibility and shall be resistant to damage from firefighting agents."⁴ Furthermore, Federal Aviation Regulation 14 CFR 139.319 (f) (2) requires emergency vehicles, "Be painted or marked in colors to enhance contrast with the background environment and optimize daytime and nighttime visibility and identification." Further guidance for the high visibility color of ARFF vehicles is provided in a Federal Aviation Administration Advisory Circular where the vehicle paint color is specified as, "lime yellow" Dupont No. 7744 UH or its equivalent.⁵

Because flight attendants are vital to the safety and survival of the passengers following a decompression, measures should be taken to prevent flight attendants from being incapacitated by hypoxia. The Safety Board believes that oxygen masks should be attached to the emergency oxygen bottles to avoid any delay in their use in order to be in compliance with the intent of 14 CFR 25.1447 (c)(4). Therefore, the FAA should direct its inspector staff to survey B-747 airplanes for compliance with 14 CFR 25.1447(c)(4), and correct deficiencies found.

In this accident, the use of megaphones was vital because of the inability to be heard over the public address (PA) system. Title 14CFR 121.309 (f)(1) requires one megaphone on each airplane with a seating capacity of more than 60 and less than 100 passengers; 14 CFR 121.309 (f)(2) requires two megaphones in the cabins on each airplane with a seating capacity of more than 99 passengers. As this decompression demonstrated, additional megaphones are necessary on wide-body and large narrow-body airplanes to ensure communication in the cabin during emergencies when the PA system is inoperative.

Had there been a need for an immediate evacuation, or a water ditching, rapid egress would not have been possible at doors 2-left and 2-right because they were blocked by open storage compartments and spilled contents. The possibility also exists that a compartment door could release during a hard landing or turbulence and swing down and injure a flight attendant. Thus, the Safety Board believes that improved latches should be installed and the downward movement of stowage compartments doors should be restricted to prevent the doors from striking a seated flight

attendant or block the exit door.

The Safety Board believes that the problems with life preserver donning and adjustment demonstrated in this accident should be addressed by the FAA. The straps and fittings on life preservers need to be evaluated to determine where improvements can be made, and clearer donning instructions should be developed. TSO-C13d, Life Preservers 1/3/83 prescribes the minimum performance standards for life preservers. With regard to donning, the TSO requires:

Donning. It must be demonstrated that an adult, after receiving only the customary preflight briefing on the use of life preservers, can don the life preserver within 15 seconds unassisted while seated. It must be demonstrated that an adult can install the life preserver on another adult, a child, or an infant within 30 seconds unassisted. The donning demonstration is begun with the unpackaged life preserver in hand.

Based on flight attendant interviews and information obtained from passengers these donning times were exceeded in many instances.

The Safety Board has made numerous recommendations to the FAA in the past regarding needed improvements in life preserver donning instructions, donning procedures, and timing of donning.⁶ The FAA has adopted most of the Safety Board's recommendations in its April 23, 1986, revision to TSO-C13e, Life Preservers, which now requires the wearer to be able to secure the preserver with no more than one attachment and make no more than one adjustment for fit. Also, donning tests are required for age groups of users starting with 20-29 years and ending with 60-69 years. At least 60% of the test subjects in each age group must be able to don then life preserver within 25 seconds unassisted with their seatbelts fastened starting with the life preserver in its storage package. TSO-C13e contains

requirements that would have eliminated some of the problems that passengers had in this accident in correctly donning and adjusting their life preservers.

The Safety Board has recommended (A-85-35 through-37) to the FAA to amend 14 CFR 121, 125, and 135 to require air carriers to install life preservers that meet TSO-C13e within a reasonable time. The FAA adopted TSO-C13e on April 23, 1986, and originally had specified an effective date of April 23, 1988, after which all newly manufactured life preservers approved under the TSO system would have to meet the requirements of TSO-C13e. The objective of the cut off date was to introduce life preservers into the fleets with the higher performance level as specified in TSO-C13e by assuring that replacement articles met the higher standards. On March 3, 1988, the FAA rescinded the cut off date to seek further public comments of fleet retrofit in accord with the proposed rulemaking. See Section 4.0 for FAA action and status of the recommendations.

3. CONCLUSIONS

3.1 Findings

1. There were no flightcrew or cabincrew factors in the cause of the accident or injuries.
2. There were no air traffic control or weather factors in the cause of the accident.
3. The airplane had not been maintained in accordance with the provisions of AD-88-12-04 that required an inspection of the cargo door locking mechanisms after each time the door was operated manually and restored to electrical operation. However, this circumstance was determined not to be a factor in the accident.
4. All but one of the electrical components remaining with the airplane or found with the cargo door that were necessary to have malfunctioned in order to cause an inadvertent electrical opening of the cargo door after dispatch were found to function properly.
5. The forward cargo door lock sectors were found in the locked position (actually in an "over-locked" position) and jammed against the latch cams. The latch cams were found in the nearly open position.
6. The latch actuator manual drive port seal was found damaged from the forces involved in the separation of the door and did not indicate that the drive port had been used to open the door latches manually before the accident.
7. Electrical continuity tests indicated that the S2 master latch lock switch was in the "not

locked" position when it was recovered with the cargo door. Because it had sustained damage from being submerged in the sea, its preaccident condition could not be determined.

8. An S2 switch functioning as found after recovery would permit electrical power to the door during ground operation so that additional failure modes or activation of the door control switch could result in movement of the latching cams.

9. All other switches associated with operation of the cargo door were found damaged from being submerged in the sea; however, they were determined to be properly installed and probably functional.

10. Short circuit paths in the cargo door circuit were identified that could have led to an uncommanded electrical actuation of the latch actuator; this situation occurred most likely before engine start, although limited possibilities for an uncommanded electrical actuation exist after engine start while an airplane is on the ground with the APU running.

11. It was not possible for electrical short circuits to command the cargo door to open at the time of the loss of the door, and it is highly improbable that such an event occurred when the airplane was airborne during the short period while the APU was running.

12. Insulation breaches were found on recovered portions of the cargo door wires that could have allowed short circuiting and power to the latch actuator, although no evidence of arcing was noted. All of the wires were not recovered, and tests showed that arcing evidence may not be detectable.

13. An uncommanded movement of cargo door latches that occurred on another UAL B-747 on June 13, 1991, was attributed to insulation damage and a consequent short between wires in the wiring bundle between the fuselage and the movable door. Because the S2 switch functioned properly on that airplane, movement of the latches would not have occurred after the door was locked.

14. UAL's maintenance trend analysis program was inadequate to detect an adverse trend involving the cargo door on N4713U.

This circumstance was determined not to be a factor in the accident.

15. FAA oversight of the UAL maintenance and inspection program did not ensure adequate trend analysis and adherence to the provisions of airworthiness directives. This circumstance was determined not to be a factor in the accident.

16. The smooth wear patterns on the latch pins of the forward cargo door installed on N4713U were signs that the door was not properly aligned (out of rig) for an extended period of time, causing significant interference during the normal open/close cycle.

17. The rough heat-tinted wear areas on the latch pins of the forward cargo door installed on N4713U marked the positions of the cams at the time the door opened in flight.

18. The design of the B-747 cargo door locking mechanisms did not provide for the intended "fail-safe" provisions of the locking and indicating systems for the door.

19. Boeing's Failure Analysis, which was the basis upon which the FAA granted an alternative method of compliance with the provisions of 14 CFR 25.783(e), was not valid as evidenced by the findings of the Pan Am incident in 1987, and the accident involving flight 811.

20. Boeing and the FAA did not take immediate action to require the use of the cam position view ports following the Pan Am incident, and did not include this requirement in the provisions of the Alert Service Bulletins or AD-88-12-04.

21. There were several opportunities for the manufacturer and the FAA to have taken action during the service life of the Boeing 747 that might have prevented this accident.

22. The fact that the crash fire rescue vehicles responding to this accident did not use a common radio frequency led to problems in communication among the responding vehicles.

23. The camouflage paint scheme of the military fire rescue units led to reduced visibility of these units and resulted in at least one near-collision.

24. Megaphones were used in flight to communicate with passengers because of the high ambient noise level. However, more megaphones would have afforded better communication in all

parts of the cabin.

25. Some flight attendants and passengers had difficulties tightening straps of their life preservers around their waists because of the fabric used, the design of the adjustment fittings, and the angle the straps were pulled.

26. Articles that fell to the floor from stowage bins above the L-2 and R-2 exits and galley service items had to be cleared away from the exits before the emergency evacuation could be initiated.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

4. RECOMMENDATIONS

As a result of the investigation, including evidence from the recovered cargo door and a June 13, 1991, incident involving the uncommanded electrical operation of a cargo door on a UAL Boeing 747 at JFK Airport, the National Transportation Safety Board recommends that the FAA:

Require that the electrical actuating systems for nonplug cargo doors on transport-category aircraft provide for the removal of all electrical power from circuits on the door after closure (except for any indicating circuit power necessary to provide positive indication that the door is properly latched and locked) to eliminate the possibility of uncommanded actuator movements caused by wiring short circuits. (Class II, Priority Action) (A-92-21)

As a result of this investigation, on August 23, 1989, the Safety Board issued the following safety recommendations to the FAA:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams. (Class II, Priority Action)(A-89-92)

Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently. (Class II, Priority Action)(A-89-93)

Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions. (Class II, Priority Action)(A-89-94)

The FAA responded to Safety Recommendations A-89-92 through -94 on November 3, 1989. During its evaluation of Safety Recommendation A-89-92, the FAA determined that Boeing 747 cargo doors with lock sectors, modified in compliance with AD 88-12-04, cannot be overridden during mechanical or

least one torque-limiting device. The Safety Board has reviewed AD 88-12-04 and has confirmed the FAA's findings. Based on this, Safety Recommendation A-89-92 has been classified as "Closed--Reconsidered."

The FAA responded to Safety Recommendations A-89-93 and -94 describing action to review all outward opening (nonplug) doors and all jetpowered transport-category airplanes to determine what, if any, modifications are needed to ensure that these doors will not open in flight. The FAA pointed out that the door latch indicating system is to be only part of the review and that door designs will be evaluated against criteria specified in 14 CFR 25.783 as amended by Amendment

25-54, and the policy material published in Advisory Circular 25.783.1, adopted in 1980 and will take into account human factors involved in the routine operation of closing and locking doors to ensure that the latch and lock systems are fail-safe. Further, to emphasize the importance of human factors, the FAA has developed a training program for FAA certification personnel to enhance their knowledge of human factors in aircraft design. This training program will be offered to approximately 100 certification personnel during the next year. Based on this response, Safety Recommendations A-89-93 and -94 have been classified as "Open--Acceptable Action." The Safety Board believes it necessary to point out that this hazard exists for any pressurized aircraft using nonplug doors and that the FAA should not be limiting this review to only those transports which are jetpowered.

On November 29, 1990, Boeing issued service bulletin number 747-52-2224 applicable to all 747-100, 747-200, and 747-300 airplanes to add a new "door latch" switch to all 747 cargo doors.

In addition to the door warning switch that monitors the position of the pressure relief doors, the new door latch switch is activated by the latch cam bellcrank to separately sense the position of the latch cams. The existing "door closed" switch is also replaced with a double pole switch. The additional pole is used to separately sense the position of the door. Another single pole switch is also added to redundantly sense the position of the door. If any of these switches are not actuated, the warning light on the flight engineer's panel and a new light added to pilot's glareshield panel will be illuminated. The modification also requires installation of new cargo door control panels on the forward and aft lower cargo doors. The new panel incorporates an additional light to indicate proper door locking.

The FAA mandated the incorporation of this service bulletin within 18 months by AD 90-09-06, Amendment 39-6581, effective May 29, 1990.

Also, as a result of this accident, on May 4, 1990, the National Transportation Safety Board issued the following safety recommendations to the FAA:

Amend 14 CFR 25.1447(c)(4) to require that face masks be attached to the regulators of portable emergency oxygen bottles. (Class II, Priority Action) (A-90-54)

Require, in accordance with the requirements of 14 CFR 25.1447(c)(4), that a portable oxygen bottle be located at the flight attendant stations at exit door 5 right and at exit door 5 left in B-747 airplanes. (Class II, Priority Action) (A-90-55)

Require that no articles be placed in storage compartments that are located over emergency exit doors. (Class II, Priority Action) (A-90-56)

Amend 14 CFR 121.309(f) to require a readily accessible megaphone at each seat row at which a flight attendant is stationed. (Class II, Priority Action) (A-90-57)

Take corrective action to improve direct visibility to passengers from the upper level flight attendant jumpseat in the B-747 airplanes using eye reference data contained in Federal Aviation Administration report FAA-AM-75-2 "Anthropometry of Airline Stewardesses." (Class II, Priority Action) (A-90-58)

Issue an Airworthiness Directive to require that stronger latches be installed in oversized storage compartments that formerly held liferafts on all B-747 airplanes and also limit the distance that these compartments can be opened. (Class II, Priority Action) (A-90-59)

Demonstrate for each make and model of life preserver that it can be donned, adjusted, and tightened within the elapsed time required by TSO-C13d. Direct particular attention to the ease with which straps pass through adjustment fittings when the straps are pulled at all possible angles. (Class II, Priority Action) (A-90-60)

Establish a cutoff date of [within 1 year of this recommendation letter] after which all life preservers manufactured for passenger carrying aircraft would be required to meet the specifications of TSO-C13e. (Class II, Priority Action) (A-90-61)

The FAA first responded to these safety recommendations in a July 26, 1990, letter. Further responses to various safety recommendations in the group came in letters dated October 26, 1990 (A-90-59); May 13, 1991 (A-90-58); September 23, 1991 (A-90-55, -56, and -59); and March 9,

1992 (A-90-59). The current status of each safety recommendation is:

A-90-54: "Open--Acceptable Response," pending outcome of potential rulemaking initiative by the FAA.

A-90-55: "Open--Unacceptable Response," pending a review by the FAA of B-747 airplanes for compliance with portable oxygen bottle placement and securement requirements and for modifications that do not meet the intent of the type certification.

A-90-56: "Open--Unacceptable Response," pending a reexamination by the FAA of the potential for contents of compartments spilling out during an emergency and obstructing passengers.

A-90-57: "Open--Unacceptable Response," pending the FAA's review of its position regarding a requirement for multiple megaphones on passenger airplanes.

A-90-58: "Closed--Reconsidered" as a result of the Safety Board's acceptance of the FAA position that the cabin jumpseat design on B-747's does not constitute an unsafe condition.

A-90-59: "Open--Acceptable Response," pending the issuance of an Airworthiness Directive to require stronger latches on oversized storage compartments on B-747 airplanes.

A-90-60: "Open--Acceptable Response," pending the implementation of the latest iteration of TSO-C13.

A-90-61: "Open--Unacceptable Response," pending inclusion in TSO-C13 (latest iteration) of a cutoff date after which all life

preservers manufactured for passenger-carrying aircraft would be required to meet the specifications of the TSO.

The FAA's March 9, 1992, response to Safety Recommendation A-90-59 included the final AD addressing this issue. The AD does meet the intent of the recommendation, which is now classified as "Closed--Acceptable Action."

Also as a result of this accident, on May 4, 1990, the Safety Board reiterated the following recommendations to the FAA:

A-85-35

Amend 14 CFR 121 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; ensure that 14 CFR 25 is consistent with the amendments to Part 121.

A-85-36

Amend 14 CFR 125 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; amend Part 125 to require approved flotation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR 25 is consistent with the amendments of Part 125.

A-85-37

Amend 14 CFR 135 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; Amend Part 135 to require approved flotation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR SFAR No. 23 is consistent with the amendments to Part 135.

In a November 28, 1988, letter to the FAA, the Safety Board recommended that a cutoff date January 1, 1989, be reestablished. Based on this accident, the Safety Board's again urges the FAA to establish a cutoff date by which life preservers meeting TSO-C13e would be introduced into the fleets within a reasonable time (A-85-36). The Safety Board recognizes that the FAA has complied with the part of this recommendation pertaining to the flotation-type seat cushions.

Safety Recommendations A-85-35 and -37 are being held in an "Open--Acceptable Action" status pending the publication of the final rule. Safety Recommendation A-85-36 is being held in an "Open--Unacceptable Action" status because Part 125 operations were not included in the FAA rulemaking action.

As a result of its investigation, on May 4, 1990, the Safety Board also recommended that the State of Hawaii, Department of Transportation, Airports Division:

Develop, in cooperation with the Department of Defense, procedures for direct radio communication between aircraft rescue and fire fighting vehicles operated by the State of Hawaii and Hickam Air Force Base that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-62)

Additionally, as a result of its investigation, on May 4, 1990, the Safety Board recommended that the Department of Defense:

Develop, in cooperation with the State of Hawaii Department of Transportation, procedures for direct radio communication between aircraft rescue and firefighting vehicles operated by Hickam Air Force Base and the State of Hawaii that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-63)

Comply with Federal Regulation 14 CFR 139.319(f)(2) and the guidance contained in Federal Aviation Administration Advisory Circular 150/5220-14 by using high visibility color for aircraft rescue and firefighting vehicles that operate at Honolulu International Airport. (Class II, Priority Action) (A-90-64)

The Department of Defense responded to Safety Recommendations A-90-63 and -64 on August 17, 1990, citing the establishment of emergency radio communication ability between ARFF vehicles operated by Hickam Air Force Base and the State of Hawaii at Honolulu International Airport. Based on this action, Safety Recommendation A-90-63 was classified as "Closed--Acceptable Action" on December 12, 1990. With the establishment of the communications system as recommended, the Safety Board now classifies Safety Recommendation A-90-62 as "Closed--Acceptable Action."

Also, with regard to Safety Recommendation A-90-64, the Department of Defense pointed out that the Air Force has initiated a program to repaint the vehicles over a 3-year period to spread out funding concerns. This safety recommendation is being held as "Open--Acceptable Response," pending the completion of the repainting program in 1993.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Member

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Member

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Member

JAMES L. KOLSTAD

Member

March 18, 1992

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Washington Headquarters of the National Transportation Safety Board was notified of the United Airlines accident within a short time after the occurrence. A full investigation team departed Washington, D.C. at 1400 eastern daylight time on the same day and arrived in Honolulu at 0030 Hawaiian standard time the next day.

The team was composed of the following investigation groups: Operations, Structures/Systems, Maintenance Records, Metallurgy, and Survival Factors. In addition, specialist reports were prepared relevant to the CVR, FDR and radar plots.

Parties to the field investigation were United Airlines, the FAA, the Boeing Commercial Airplane

Company, the Air Line Pilots Association, the International Association of Machinists, and the Association of Flight Attendants.

2. Public Hearing

A 3-day public hearing was held in Seattle, Washington, beginning on April 25, 1989. Parties represented at the hearing were the FAA, United Airlines, the Boeing Commercial Airplanes Company, the Air Line Pilots Association, and the International Association of Machinists.

APPENDIX B

PERSONNEL INFORMATION

Captain David Cronin

Captain David Cronin, 59, was hired by UAL on December 10, 1954. The captain holds Airline Transport Pilot (ATP) Certificate No. 1268493 with airplane multiengine land ratings and commercial privileges in airplane single-engine land, sea and gliders. The captain is type rated in the B747, DC10, DC8, B727, Convair (CV) 440, CV340, CV240 and the Lear jet. The captain was issued a first class medical certificate on November 1, 1988, with no limitations.

The captain's initial operating experience (IOE) check out in the B747 occurred in December, 1985. The captain's latest line and proficiency checks in the B747 were completed in August and December, 1988, respectively. Training in ditching and evacuation was included with the proficiency check. The captain had flown a total of about 28,000 hours, 1,600 to 1,700 hours of which were in the B747. During the 24-hour, 72-hour and 30-day periods, prior to the accident, the captain had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 76 hours, 18 minutes, respectively.

First Officer Gregory Slader

First Officer Gregory Slader, 48, was hired by UAL on June 15, 1964. The first officer holds ATP Certificate No. 1528630 with airplane multiengine land ratings and commercial privileges in airplane single-engine land. The first officer is type rated in B747, DC10, B727, and B737. The first officer was issued a first class medical certificate on February 14, 1989, with no limitations.

The first officer's initial operating experience (IOE) check out in the B747 occurred in August, 1987. The first officer's latest proficiency check in the B747 was completed in October, 1988. Training on ditching and evacuation was included with the proficiency check. The first officer had flown a total of about 14,500 hours, 300 hours of which were in the B747. During the 24-hours, 72-hour and 30-day periods prior to the accident, the first officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes, respectively.

Second Officer Randal Thomas

Second Officer Randal Thomas, 46, was hired by UAL on May 22, 1969. The second officer holds Flight Engineer Certificate No. 1947041 for turbo jet powered airplanes, issued July 18, 1969. The second officer holds commercial pilot certificate No. 1585899 with ratings and limitations of airplane single and multiengine land with instrument privileges. The second officer was issued a first class medical certificate on December 6, 1988, with no limitations.

The second officer's IOE check out in the B747 occurred in March, 1987. The second officer's latest proficiency check in the B747 was completed in October, 1988. Training in ditching and evacuation was included with the proficiency check. He had flown a total of about 20,000 hours, about 1,200 hours of which were as second officer on the B747. During his 24-hour, 72-hour and 30 day-periods, prior to the accident, the second officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes, respectively.

Flight Attendant and Chief Purser Laura Brentlinger

Flight attendant Laura Brentlinger, 38, was employed by UAL in May 1982; and had completed B747 recurrent training on September 19, 1988.

Flight Attendant and AFT Purser Sarah Shanahan

Flight attendant Sarah Shanahan, 42, was employed by UAL in August 1967; and had completed B747 recurrent training on October 10, 1988.

Flight Attendant Richard Lam

Flight attendant Richard Lam, 41, was employed by UAL on April 1970; and had completed B747 recurrent training on September 16, 1988.

Flight Attendant John Horita

Flight attendant John Horita, 44, was employed by UAL in June 1970; and had completed B747 recurrent training on November 1, 1988.

Flight Attendant Curtis Christensen

Flight attendant Curtis Christensen, 34, was initially employed by PAA in May 1978. He was subsequently employed by UAL in February 1986 when UAL purchased PAA Pacific Division. Flight attendant Christensen had completed B747 recurrent training on December 12, 1988.

Flight Attendant Tina Blundy

Flight attendant Tina Blundy, 36, was employed by UAL in May 1973; and had completed B747 recurrent training on October 28, 1988.

Flight Attendant Jean Nakayama

Flight attendant Jane Nakayama, 37, was employed by UAL in August 1973; and had completed B747 recurrent training on December 6, 1988.

Flight Attendant Mae Sapolu

Flight attendant Mae Sapolu, 38, was initially employed by Pan American Airlines (PAA) in March 1973. She was subsequently employed by UAL in February 1986; when UAL purchased PAA Pacific Division. Flight attendant Sapolu completed B747 recurrent training on October 13, 1988.

Flight Attendant Robyn Nakamoto

Flight attendant Robyn Nakamoto, 26, was employed by UAL in April, 1986, and transferred to the Inflight Service Division in May, 1988. She was initially trained on the B747 in May 1988; and had not attended recurrent training.

Flight Attendant Edward Lythgoe

Flight attendant Edward Lythgoe, 37, was employed by UAL in December 1978; and had completed B747 recurrent training on October 21, 1988.

Flight Attendant Sharol Preston

Flight attendant Sharol Preston, 39, was employed by UAL in July 1970; and had completed B747 recurrent training on July 29, 1988.

Flight Attendant Ricky Umehira

Flight attendant Ricky Umehira, 35, was employed by UAL in November 1983; and had completed B747 recurrent training on November 15, 1988.

Flight Attendant Darrell Blankenship

Flight attendant Darrell Blankenship, 28, was employed by UAL in February 1984; and had completed B747 recurrent training on February 10, 1988.

Flight Attendant Linda Shirley

Flight attendant Linda Shirley, 30, was employed by UAL in March 1979; and had completed B747 recurrent training on November 3, 1989.

Flight Attendant Ilona Benoit

Flight attendant Ilona Benoit, 48, was initially employed by PAA in November 1969. She was subsequently employed by UAL in February 1986; and had completed B747 recurrent training on November 17, 1988.

Lead Ramp Serviceman Paul Engalla

Lead ramp serviceman Paul Engalla was employed by UAL in 1959. Because of his extensive ramp service experience, Mr. Engalla was selected as a ramp service trainer in 1986.

Ramp Serviceman Daniel Sato

Ramp serviceman Daniel Sato was employed by UAL in May 1987. Company records indicate that his proficiency in the opening and closing of B747 cargo doors and the operation of container loads was attained in September 1988.

Ramp Serviceman Brian Kitaoka

Ramp serviceman Brian Kitaoka was employed by UAL in November 1986. Company records

indicate that his proficiency in the operation of container loaders was attained in November 1987. His proficiency in the opening and closing of B747 cargo doors was attained in October 1988.

Dispatch Mechanic Steve Hajanos

Dispatch mechanic Steve Hajanos was employed as an airplane mechanic by UAL on October 30, 1986. He holds FAA Airplane and Powerplants Certificate No. 362583850, issued November 14, 1981. He was formerly employed by Aloha Airlines as a maintenance supervisor and by World Airways as a mechanic and maintenance supervisor. He began his aviation career as an airplane mechanic in the United States Air Force.

APPENDIX C

AIRPLANE INFORMATION

Type of Date of Maximum Inspection Inspection Cycles Interval Service No. 1 Current 02/23/89 58,814:24 15,027 Note 1 Previous 02/23/89 58,809:02 15,026 Service No. 2 Current 02/22/89 58,802:35 15,024 65 Hours Previous 02/18/89 58,747:12 15,016 Note 2 A Check Current 02/14/89 58,710:14 15,009 350 Hours Previous 01/16/89 58,368:57 14,947 B Check Current 11/28/88 57,751:44 14,839 131 Days Previous 07/28/88 56,635:36 14,632 C Check Current 11/28/88 57,751:44 14,839 393 Days Previous 11/19/87 53,789:00 14,146 MPV Check Current 04/30/84 43,731:0 11,857 5 Years Previous 01/30/80 30,906:0

D Check Current 04/30/84 43,731 19,237 9 Years Previous 09/09/76 19,237 Note 1: Service No. 1 to be accomplished on through flights or at trip termination whenever time is less than 12 hours per Maintenance Manual Procedures BX 12-0-1-1.

Note 2: Aircraft with layover of 12 hours or more will receive a Service No. 2 not to exceed 65 flight hours between checks.

APPENDIX D

INJURY INFORMATION

Flight Crewmember.--The second officer sustained minor superficial brush burns to both elbows and forearms, during the evacuation.

Cabin Crewmembers.--The cabin crewmembers sustained the following injuries during the evacuation:

Flight attendant No. 1 sustained a strained left shoulder;

Flight attendant No. 2 sustained acute thoracic and lumbosacral strain;

Flight attendant No. 3 sustained a mild right bicep strain;

Flight attendant No. 4 sustained a left elbow contusion, left shoulder dislocation, and mild lumbosacral strain;

Flight attendant No. 5 sustained a left calf contusion;

Flight attendant No. 6 sustained a mild left elbow bruise;

Flight attendant No. 7 sustained mild left arm and lower back strain;

Flight attendant No. 8 sustained a soft tissue injury to the back;

Flight attendant No. 9 sustained abrasions to both palms and the left knee;

Flight attendant No. 10 sustained a fracture of the left tenth rib;

Flight attendant No. 11 sustained a minimal injury to the right middle finger PIP joint and left first MP joint;

Flight attendant No. 12 sustained a pulled muscle on the left side of the neck;

Flight attendant No. 13 sustained a comminuted fracture of the right ulna and radius;

Flight attendant No. 14 sustained a mild thoracic back strain;

Flight attendant No. 15 sustained a non-displaced fracture of C-6, a cerebral concussion, a fracture of the proximal right humerus, and multiple lacerations;

A flight attendant, flying as a passenger, sustained mild lumbosacral strain, a laceration of the right little finger, and a left elbow abrasion.

Passengers.--Nine Passengers who were seated in seats 8H, 9FGH, 10GH, 11GH, and 12H, were ejected from the fuselage and were not found; and thus, are assumed to have been fatally

injured in the accident.

Passengers seated in the indicated seats sustained the following injuries:

Seat

- 7C - Barotrauma to both ears
- 9C - Half-inch laceration to the upper left arm, superficial abrasions to left arm and hand, barotrauma to both ears
- 9E - Superficial abrasions and contusions to the left hand, mild barotrauma to both ears
- 10B - Superficial abrasions to the left elbow and left middle finger
- 10E - Superficial abrasions to the torso and left forearm, bruising of the left hand and fingers
- 11E - Laceration on the right ankle tendon, multiple bruises
- 11F - Slight contusion of the right shoulder
- 13D - Barotrauma to both ears
- 13E - Bleeding in both ears
- 13H - Contusion to the left periorbital area
- 14A - Laceration in the parietal occipital area, barotrauma to both ears
- 15J - Comminuted fracture of the lateral epicondyle of the left distal humerus (about 5mm separation)
- 16B - Superficial abrasions to the right arm
- 16J - Barotrauma to both ears
- 16K - Right temporal abrasions
- 26A - Barotrauma to both ears
- 26B - barotrauma to both ears
- 26H - Barotitis to both ears, low back pain, irritation to the right eye due to foreign bodies
- 27A - Barotrauma to the right ear
- 28J - Superficial abrasions and a contusion to the left hand, mild barotrauma to both ears

1The flap track canoe fairings are numbered 1 through 8, from left outboard to right outboard.

2For ease in reference, the following numbering was used to relate forward cargo door frames to fuselage body stations (BS): frame 1--BS 567.10, frame 2--BS 580.95, frame 3--BS 596.75, frame 4--BS 608.15, frame 5--BS 623.96, frame 6--BS 636.02, frame 7--BS 651.50, frame 8--BS 662.90.

3 The "used" switch is the switch through which electricity passes; the "unused" switch does not have electricity pass through it.

4NFPA 414 - Aircraft Rescue and Fire Fighting Vehicles, National Fire Protection Association, 1984, Batterymarch Park, Quincy, MA 02269.

5Airport Fire and Rescue Vehicle Specification Guide, AC 150/5220-14, March 15, 1979, Federal Aviation Administration, Washington, D.C. 20591.

6 Air Carrier Overwater Emergency Equipment and Procedures" (NTSB/SS-85/02)

**Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21 December 1988
by John Barry Smith,
Independent Aircraft Accident Investigator**

Appendix N: Pressure Relief Doors



Normal Boeing 747 forward cargo door showing aft and forward pressure relief doors near top hinge.

From NTSB AAR 92/02 for United Airlines Flight 811: 'The cargo doors on the B-747 have a master latch lock handle installed on the exterior of the door. The handle is opened and closed manually. The master latch lock handle simultaneously controls the operation of the latch lock sectors, which act as locks for the latch cams, and the two pressure relief doors located on the door. The final securing operation is the movement of lock sectors across the latch cams. These are manually moved in place across the open mouth of each of the eight lower cams through mechanical linkages to the master latch lock handle. The position of the lock sectors is indicated indirectly by noting visually the closed position of the two pressure relief doors located on the upper section of each cargo door. The pressure relief doors are designed to relieve any residual pressure differential before the cargo doors are opened after landing, and to prevent pressurization of the airplane should the airplane depart with the cargo doors not properly secured. The pressure relief doors are mechanically linked to the movement of the lock sectors. This final procedure also actuates the master latch lock switch, removing electrical control power from the opening and closing control circuits, and also extinguishes the cockpit cargo door warning light through a switch located on one of the pressure relief doors.'



United Airlines Flight 811 forward cargo door showing missing aft pressure relief door and jammed open status of forward pressure relief door according to NTSB AAR 92/02.

Below excerpts for NTSB AAR 92/02 for United Airlines Flight 811:

‘The ramp service personnel said that they had verified that the forward cargo door was flush with the fuselage of the airplane, that the master door latch handle was stowed, and that the pressure relief doors were flush with the exterior skin of the cargo door. The dispatch mechanic stated that, in accordance with UAL procedures, he had performed a "circle check" prior to the airplane's departure from the HNL gate. This check included verification that the cargo doors were flush with the fuselage of the airplane, that the master latch lock handles were stowed, and that the pressure relief doors were flush or within 1/2 inch of the cargo door's exterior skin. He said a flashlight

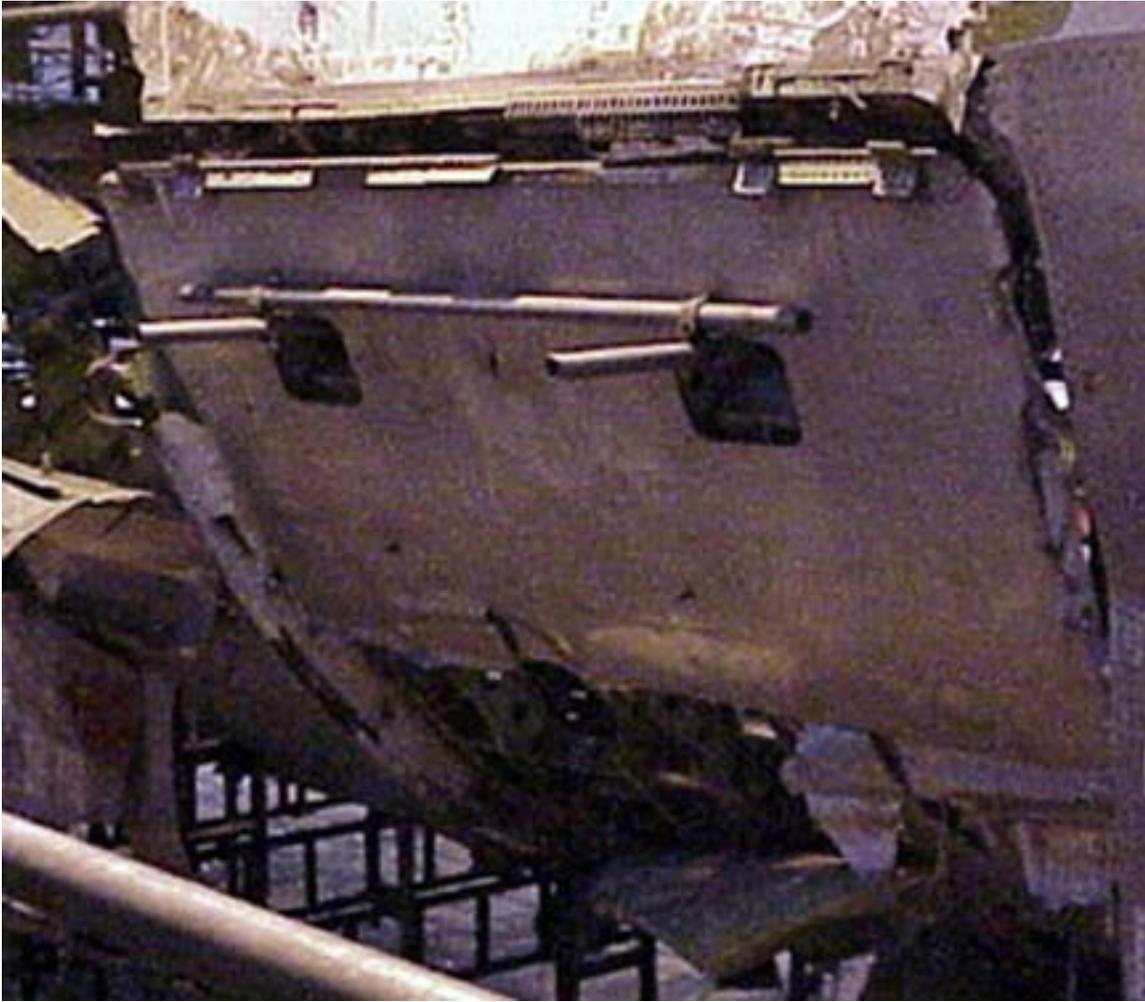
was used during this inspection.’

SB-747-52-2097, "Pressure Relief Door Shroud Installation--Lower Lobe and Side Cargo Doors," was issued on June 27, 1975. Revision 1 to SB-747-52-2097 was issued November 14, 1975. In general, the SB recommended the installation of shrouds on the inboard sides of the cargo door pressure relief door openings. The purpose of the shrouds was to prevent the possibility of the pressure relief doors being rotated (blown) to the closed position during the pressurization cycle. This condition could only occur if the master latch lock handle had been left open and the flightcrew failed to note the cargo door open warning before takeoff.’

‘UAL records for N4713U indicated that SB-747-52-2097 had been complied with and the shrouds had been installed on the forward and aft cargo doors. However, examination of the aft cargo door on N4713U revealed that the shrouds were not in place. UAL could not find records to verify if the shrouds had been installed or if they had been removed from either door. There was no evidence of the pressure relief door shrouds found on the forward door; however, most of the inner door lining to which the shrouds attach was missing.’

‘The lower two connecting rods between the lock sector torque tube and the torque tube below the pressure-relief doors were undamaged; however, the upper connecting rod had separated at the upper, tapered end. The torque tube below the pressure-relief doors were missing, and the pressure-relief door connecting rods had separated at the lower, tapered end. The remaining portion of each rod was undamaged, but the forward pressure-relief door was jammed open into the cutout.’

‘The examination of the recovered forward cargo door did not provide confirmation that the pressure relief door shrouds were actually installed on the forward door, although UAL records showed that they had been installed on both cargo doors of N4713U, in accordance with SB-747-52-2097. However, the shrouds were found not to be installed on the aft door, contrary to UAL records, and therefore may not have been installed on the forward door. Without the shrouds, the pressure relief doors could have rotated shut during the pressurization cycle. Because the closure of the pressure relief doors would back-drive the lock sectors, this scenario would presume previous damage to the sectors, which would permit the sectors to move over the unlatched cams.’



Pan Am Flight 103 Forward cargo door showing missing aft and forward pressure relief doors.

No reference is made in AAIB AAR 2/90 for Pan Am Flight 103 to any pressure relief door in any cargo door for Pan Am Flight 103.



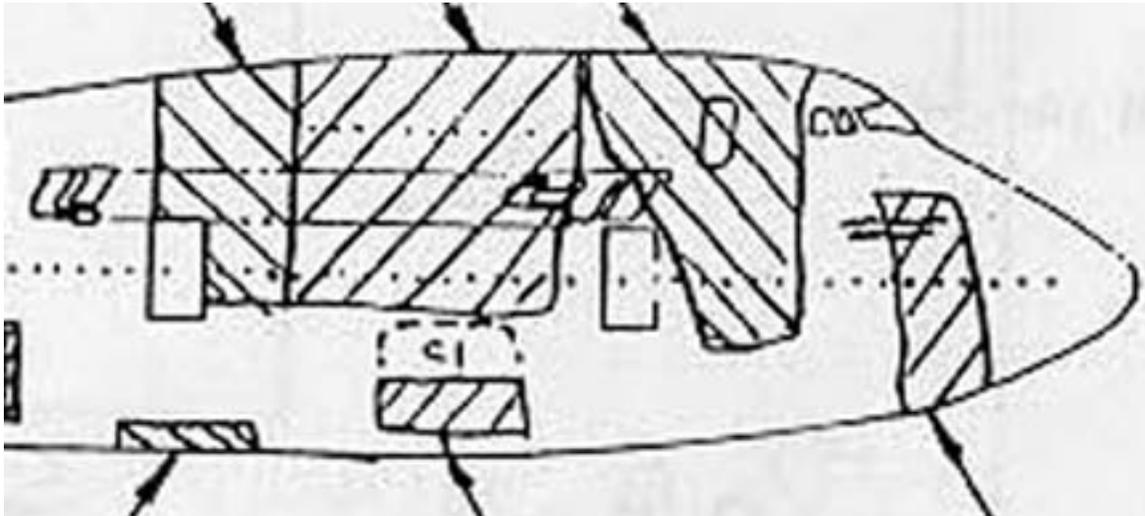
Trans World Airlines Flight 800 Forward cargo door showing missing aft pressure relief door.

No reference is made to any pressure relief door in any cargo door in NTSB AAR 00/03 for Trans World Airlines Flight 800.



Trans World Airlines Flight 800 Forward cargo door showing separated and replaced forward pressure relief door.

No reference is made to any pressure relief door in any cargo door in NTSB AAR 00/03 for Trans World Airlines Flight 800.



Air India Flight 182 Forward cargo door showing missing top half of door including the aft and forward pressure relief doors.

No reference to any pressure relief door in any cargo door in CASB and Kirpal AAR for Air India Flight 182

From the Canadian Aviation Occurrence Report: '2.11.4.6 All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different than that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back onto the sea bed. An attempt to relocate the door was unsuccessful.'

Conclusion:

The missing and jammed pressure relief doors in the forward cargo doors of aircraft that suffer and explosive decompression in the forward cargo compartment indicate that internal pressures were not normal and require satisfactory explanation. The status of the pressure relief doors needs to be determined for Pan Am Flight 103, Trans World Airlines Flight 800, and Air India Flight 182.

The pressure relief doors are not designed to blow out if abnormal internal pressure detected. They are mechanically linked to the latching mechanisms. If the latches inadvertently turn towards the unlatched position in flight, the pressure relief doors would slightly open also. When the pieces of the cargo door fell from a great height, the relief doors might have become jammed or lost upon ground or water impact. The pressure relief doors may have been recovered in the wreckage but not hung on the wreckage reconstruction.

At this time, this investigator has no explanation for the similar anomalies of the jammed and missing pressure relief doors in the cargo doors.