This Submission by the Canadian Aviation Safety Board was prepared to assist the Indian Inquiry into the crash involving Air India Flight 182 on 23 June 1985.

AVIATION OCCURRENCE

AIR INDIA
BOEING 747-237B VT-EFO
CORK, IRELAND 110 MILES WEST
23 JUNE 1985

SYNOPSIS

Air India Flight 182, a Boeing 747, was on a flight from Mirabel to London when it disappeared from the radar scope at a position of 51°N latitude and 12°50'W longitude at 0714 Greenwich Mean Time, 23 June 1985, and crashed into the ocean about 110 miles west of Cork, Ireland. There were no survivors among the 329 passengers and crew members.

NOTE

The Board prepared this Submission for the purpose of advancing aviation safety; it is not the object of the Board to determine or apportion any blame or liability. Our ultimate objective in any investigation is the identification of safety deficiencies, whether causal or not, and of appropriate corrective measures that may be recommended to the regulatory and enforcement authorities for implementation.

1.0 INTRODUCTION

Air India Flight 182, a Boeing 747-237B, registration VT-EFO, was on a flight from Mirabel to London when it disappeared from the radar scope at a position of latitude 51°0'N and longitude 12°50'W at 0714 Greenwich Mean Time (GMT), 23 June 1985, and crashed into the ocean about 110 miles west of Cork, Ireland. There were no survivors among the 329 passengers and crew members. The depth of the water at the crash site is about 6,700 feet.

At 0541 GMT, 23 June 1985, CP Air Flight 003 arrived at Narita Airport, Tokyo, Japan, from Vancouver. At 0619 GMT a bag from this flight exploded on a baggage cart in the transit area of the airport within an hour of the Air India occurence. Two persons were killed and four were injured. From the day of the occurrences, there have been questions about a possible linkage between the events.

This Submission examines the information available to the Canadian Aviation Safety Board (CASB) with respect to the circumstances surrounding the AI 182 accident. The sources of information include: information made public to the Indian Inquiry as a result of the RCMP investigation; the flight data recorder (FDR), cockpit voice recorder (CVR) and Shannon ATC tape recording analyses by Canadian, United Kingdom, and Indian authorities; the medical evidence obtained from Dr. Hill of the Accident Investigations Branch of the United Kingdom; and the evidence obtained by examination of the wreckage recovered, the wreckage distribution pattern, photographs, and videotapes of the wreckage on the ocean bottom.

2.0 EXAMINATION

2.1 Vancouver

On 19 June 1985, at approximately 1800 PDT (0100 GMT, 20 June), a CP Air reservations agent in Vancouver received a telephone call from a male with a slight East Indian accent.* He identified himself as Mr. Singh and informed the agent that he was making bookings for two different males also with the surname of Singh. One booking was made in the name of Jaswand Singh with CP 086 from Vancouver to Dorval on 22 June 1985 to link with AI 182 departing from Mirabel. The other booking was to Bangkok using CP 003 from Vancouver to Tokyo and AI 301 from Tokyo to Bangkok. This booking was made in the name of Mohinderbel Singh. A local telephone contact number was given and the call lasted about one-half hour.

On the same date at approximately 1920 PDT (0220 GMT), another reservations agent for CP Air was contacted and requested to change the booking for Jaswand Singh. The confirmed flight on CP 086 was cancelled and a reservation was made on CP 060 from Vancouver to Toronto, and a request to be wait-listed on AI 181/182 from Toronto to Delhi was made.

On 20 June 1985 at about 1210 PDT (1910 GMT), a male appearing to be of East Indian origin purchased the tickets with cash from a CP Air ticket office in Vancouver. The booking in the name of Mohinderbel Singh was changed to L. Singh and the booking using the name of Jaswand Singh changed to M. Singh. The telephone contact number was also changed. The final itinerary was as follows:

a) M. Singh - CP 060 Vancouver - Toronto
Confirmed
Scheduled to depart Vancouver at 0900 PDT, 22 June 1985

- AI 181 Toronto - Montreal
Wait-listed
Scheduled to depart Toronto at 1835 EDT, 22 June 1985

*See Appendix A for chronology of events.

- AI 182 Montreal - Delhi
  Wait-listed
  Scheduled to depart Montreal at 2020 EDT,
  22 June 1985

b) L. Singh - CP 003 Vancouver - Tokyo
  Confirmed
  Scheduled to depart Vancouver at 1315 PDT,
  22 June 1985

- Air India 301 Tokyo - Bangkok
  Confirmed
  Scheduled to depart Tokyo at 1705 (local time in Tokyo),
  23 June 1985

On 22 June 1985 at about 0630 PDT (1330 GMT), a caller identifying himself as Mr. Manjit Singh called the CP Air reservations office. The caller spoke with a heavy East Indian accent and wanted to know if his booking on AI 181/182 was confirmed. The caller was informed by the agent that he was still wait-listed out of Toronto and offered to make alternate arrangements to Delhi. The caller stated that he would rather go to the airport and take his chances. The caller also asked if he could send his luggage from Vancouver to Delhi and was told he could not check his baggage past Toronto unless his flight was confirmed.

On Saturday morning, 22 June 1985, a CP Air passenger agent worked check-in position number 26 at the CP Air ticket counter, Vancouver International Airport, and recalls dealing with a passenger booked on CP 060 and then on to Delhi. The passenger stated that he wanted his bag tagged right to Delhi from Vancouver. After checking the computer, the agent explained that since he was not confirmed past Toronto he could not interline his baggage. The passenger insisted and, as the line-ups were long, the agent relented and interlined his suitcase. The flight manifest for CP 060 shows that M. Singh checked in through this passenger agent, was assigned seat 10B, and checked one piece of baggage. The flight manifest for CP 003 shows that on the same day the person using the name of L. Singh with a ticket to Bangkok also checked in through the same counter, was assigned seat 38H, and checked one piece of baggage.

A check of CP Air's records and interviews with passengers on flights CP 003 and CP 060 indicates that the persons identifying themselves as M. and L. Singh did not board these respective flights.

2.2 Toronto

Air India Flight 181 from Frankfurt arrived at Toronto on 22 June 1985 at 1430 EDT (1830 GMT) and was parked at gate 107 of Terminal 2. All passengers and baggage were removed from the aircraft and processed through Canada Customs. Passengers continuing on the flight to Montreal were given transit cards, and on this flight 68 cards were handed out. These transit passengers are required to claim their luggage and proceed through Canada Customs. Prior to entering the public area, there is a belt which is designated for interline or transit baggage. Transit passengers deposit their luggage on this belt which carries it to be reloaded on the aircraft. This baggage was not subjected to X-ray inspection as it was presumed to have been screened at the passengers' overseas departure point. When the transit passengers checked in to proceed to Montreal, their carry-on baggage was subjected to the normal security checks in place on this date. Passenger and baggage security checks were conducted by Burns International Security Services Ltd. and all passenger and baggage processing for both off-loading and on-loading was handled by Air Canada staff.

Air India Flight 181 was composed of the following:

- passengers continuing to Montreal (68)

- passengers from connecting flights
  AC 102 (Saskatoon) 2
  AC 106 (Edmonton) 4
  AC 192 (Winnipeg) 1
  AC 170 (Winnipeg) 4
  AC 136 (Vancouver) 10
  CP 060 (Vancouver) 1 Standby (M. Singh)

- passengers originating at Toronto

- diplomatic bags from the Vancouver India Consul General via AC 508

- produce cargo from India

- cargo in the form of 5th pod engine components loaded in the aft cargo compartment.

It should be noted that some passengers from India book flights to Montreal with their intended destination being Toronto. The reason is that the fare to Montreal is cheaper and therefore some passengers get off the flight in Toronto, claim their luggage and leave without reporting a cancellation of the trip to Montreal. It has been established that 65 of the 68 transit passengers reboarded the flight to Montreal.

Air India personnel were in charge for the overall operation at Toronto regarding the unloading and loading of both passengers and cargo. Although the actual work was performed by various companies under contract, Air India personnel oversaw the operation. The Air India station manager was away on vacation on 22 June 1985. The evidence does not clearly establish who had been assigned to replace the station manager and assume his duties.

Air Canada had stored in a hangar an engine that had failed on a previous Air India flight from Toronto on 8 June 1985. Air Canada received a message from Air India stating that the failed engine was to be mounted as a 5th pod on Flight 181/182 on 22 June 1985. The engine was prepared for loading and component parts were crated for loading into the aft cargo compartment. On 22 June, the component parts were taken from the hangar and placed outside to be delivered to the aircraft by MEGA International Air Cargo. The component parts were placed just inside the airport fence separating the restricted and unrestricted areas. The installation began immediately upon the arrival of Flight 181 and was completed at 1530 EDT (1930 GMT). The front engine cowling was crated but would not fit through the aft cargo door. The crating was rearranged, and the door stops on the cargo door were removed to permit the loading of the crate and the remaining engine parts were loaded on pallets. Due to problems with loading the 5th pod and component parts, the departure was delayed from 1835 EDT (2235 GMT) to 2015 EDT (0015 GMT, 23 June).

CP Air Flight 060 arrived in Toronto at 1610 EDT (2010 GMT) and docked at gate 44, Terminal 1. A number of passengers on this flight were interlined to other flights including passenger M. Singh wait-listed on Air India Flight 181/182. It has been established that this passenger did not board Flight CP 060 but did check baggage onto the flight. This baggage was to be interlined to the Air India flight departing from Terminal 2. In this case, CP Air employees would have off-loaded all baggage from CP 060 and deposited the baggage at Racetrack 6 on the ring road of Terminal 1 to be transported to the Air Canada sorting room at Terminal 2.

Consolidated Aviation Fuelling and Services (CAFAS) is a company which is contracted to pick up and deliver baggage from one terminal to the other. The CAFAS driver on duty at the time recalls picking up a bag from a CP Air flight originating in Vancouver and destined for Air India at Terminal 2. As this piece of luggage did not turn up as found luggage, it is deduced that normal practice was followed, and the luggage was interlined and loaded on AI 181/182.

MEGA International Air Cargo is a firm that handled air cargo and containers for Air India. Since the flight was carrying a 5th engine and component parts, no commercial cargo could be loaded at Toronto. MEGA delivered the engine component parts to be loaded in the cargo compartment by Air Canada employees. Later, MEGA received two diplomatic bags and delivered these to the aircraft. The bags were loaded into the valuable goods container (see Appendix B). These bags were not subjected to X-ray or any other security checks.

All checked-in baggage for AI 181/182 was to be screened by an X-ray machine which was located in Terminal 2 at the end of international belt number 4. This location would permit all baggage from the check-in counters and interline carts to be fed through the X-ray machine before being loaded. It has been established that this machine worked intermittently for a period of time and stopped working during the loading process at about 1700 EDT (2100 GMT). Rather than opening the bags and physically inspecting them, the Burns security personnel performing the X-ray screening were told by the Air India security officer to start using the hand-held PD-4 sniffer.

One Burns security officer checked the bags with the sniffer while another put stickers on the bags and forwarded them. The security officer forwarding the baggage recalls the sniffer making short beeping noises not long whistling ones. The security officer who used the sniffer claims it never went off, and the only time any sound was made was when it was turned on and off. At those times, it would emanate a short beep (refer to section 2.8 for further information regarding the PD-4 sniffer).

Burns International Security had a contract with Air India for the security of the aircraft while it was docked. The security arrangements contracted from Burns were as follows:

- security at the bridge door leading to the aircraft;

- security inside the aircraft from the time the passengers disembarked upon flight arrival until flight departure;

- security guards assigned the physical inspection of all carry-on baggage in the departure room; and

- security guards in the international baggage make-up room conducting screening of baggage using an X-ray machine and a hand-held PD-4 sniffer.

The statements taken from Burns security personnel in Toronto indicated that a significant number of personnel, including those handling passenger screening, had never had the Transport Canada passenger inspection training program or, if they had, had not undergone refresher training within 12 months of the previous training.

As a result of official requests made by Air India in early June 1985 for increased security for Air India flights, the RCMP provided additional security as follows:

- one member in a marked police motor vehicle patrolling the apron area;

- one member in a marked police motor vehicle parked under the right wing from time of arrival until push-back;

- one member on foot patrol at Air India check-in counter; and

- one member at the loading bridge during boarding.

In addition, all RCMP members working in that particular area of Terminal 2 were aware of the Air India flight and would check in with the assigned personnel during their patrols in the area of the aircraft and check-in/boarding lounges. Uniformed members are to patrol and monitor security within the airport premises as detailed in section 2.5 below.

Passenger check-in was handled for Air India by Air Canada under contract with Air India. The check-in included passengers originating in Toronto and interline passengers but did not include the transit passengers to Montreal. The check-in passengers were numbered using a security control sheet in accordance with instructions from Air India; however, the check-in and interline baggage was not numbered, and no attempt was made to correlate baggage with passengers. Hence, any unaccompanied interline baggage would not have been detected.

The flight and cabin crew had been in Toronto for the week prior to this flight and were to take the aircraft to London where they would be replaced by another crew. The crew members themselves and their carry-on baggage were not subjected to any security checks; however, their checked-in baggage was screened in the same manner as other baggage.

2.3 Montreal

Air India Flight 181 from Toronto arrived at Mirabel International Airport at about 2100 EDT (0100 GMT, 23 June) and parked in supply area number 14 at 2106 EDT (0106 GMT). The 65 passengers destined for Montreal along with three Air India personnel deplaned and were transported by bus to the terminal building. The remaining passengers remained on board as transit passengers and were not permitted to disembark at Montreal. Air Canada baggage handlers off-loaded four containers of cargo, three containers of baggage and a valuables container. Two diplomatic pouches from the Indian High Commission in Ottawa were delivered to the aircraft by MEGA International Cargo. One pouch weighing

one kilogram was hand-delivered to the flight purser for storage in a valuables locker within the cabin and the other pouch was loaded into the valuables container.

During the check of the aircraft at Montreal, the second officer pointed out to an Air Canada mechanic that a rear latch on the fan cowl for the 5th engine did not appear to be properly secured. The mechanic examined the latch and found it well secured, but the handle was not flush and was hanging about five degrees. The mechanic applied high-speed tape to the latch handle for aerodynamic smoothness. This repair was examined by the second officer who was satisfied with the work. No records were completed by Air Canada in connection with this temporary repair.

At about 1730 EDT (2130 GMT), Air Canada, which is Air India's contracted agent, opened its check-in counter to passengers who would be flying on Air India Flight 182. Burns security personnel were also assigned at this time to screen the checked baggage. Passenger tickets were checked, issued a number, and copies of the tickets were removed and retained by Air Canada. Boarding passes were then issued and affixed to the numbered tickets. Also attached to the ticket booklets were numbered tickets which corresponded to each piece of checked baggage. The numbered checked baggage was sent to the baggage area by Air Canada personnel to be security-checked by Burns security personnel.

The passengers for AI 182 after checking in were free to enter the departure area. At the entrance to the departure area, Burns security staff used X-ray units and metal detectors to screen passengers and carry-on baggage. At about 2100 EDT (0100 GMT), the passengers proceeded to gate 80 where they gave their boarding passes and numbered tickets to an Air Canada agent. The agent kept the numbered flight tickets and checked the numbers against the passenger list. Also, at gate 80, a secondary security check was done on passengers by a Burns security officer using a metal detector. Hand-carried baggage was subjected to further physical and visual checks. A total of 105 passengers boarded the flight at Mirabel Airport; there were no interline passengers.

Between 1900 (2300 GMT) and 1930 EDT (2330 GMT), Burns security personnel identified a suspect suitcase using the

X-ray machine. The suitcase was placed on the floor next to the machine. The Burns security supervisor told Air India personnel that a suspect suitcase had been located and was advised within 15 to 20 minutes to wait for the Air India security officer who would be arriving on the flight from Toronto. Subsequently, a second suspect suitcase was identified and a little later a third. The three suitcases were placed next to the X-ray machine. Between 1930 (2330 GMT) and 1945 (2345 GMT), all the Burns security personnel at the X-ray machine were assigned to other duties and the three suspect suitcases remained in the baggage area without supervision. At about 2140 (0140 GMT), the Air India security officer went to the baggage room and inspected the three suitcases with the X-ray machine and a sniffer that was in the possession of the security officer. The Air India security officer decided to keep the three suitcases and, if further examination proved negative, send them on a later flight. At approximately 2155 (0155 GMT), the Air Canada Operations Centre supervisor contacted the airport RCMP detachment regarding the suspect suitcases. At about 2205 (0205 GMT), an RCMP member located the suitcases in the baggage room and requested that an Air India representative be sent to the baggage room. About five minutes later, the Air India security officer contacted the baggage room by telephone and advised that he could not come to the room immediately. The Air India security officer arrived in the baggage room at about 2235 (0235 GMT) and, when asked to determine the owners of the suitcases, informed the RCMP member that the flight had already departed [2218 (0218 GMT)]. The three suspect suitcases were later examined with negative results.

The remainder of the checked baggage which cleared the security check was identified by a green sticker. The baggage was then forwarded to Air Canada personnel who loaded the baggage in containers to be placed on board the aircraft. A later check with Canada Customs and Air Canada at Mirabel revealed no unclaimed baggage associated with AI 181/182. A similar check at Dorval Airport was conducted with negative results.

No record was kept as to the location and number of individual pieces of checked-in luggage. Records were kept as to the location of the containers according to destination, where loaded and the number of pieces of luggage in each container (see Appendix B).

The Mirabel Detachment of the RCMP provided the following security at the airport on 22 June 1985:

- one member in a police vehicle for airside security;
- one member on patrol in the arrival and departure areas;
- one member on general foot patrol throughout the terminal; and
- one member as a telecommunications operator in the detachment office.

In addition, due to the increased threat to Air India flights, the RCMP provided the following supplementary coverage to Air India Flight 181/182 on 22 June 1985:

- one member in a police vehicle escorted the aircraft to and from the runway and the terminal building and remained with the aircraft while it was stationary;
- one member in a police vehicle remained at the entrance to the ramp;
- two members patrolled the area of the ticket counter and access corridors, and one of these members also served in a liaison capacity with the airline representatives.

2.4 International Standards and Recommended Practices

International security standards and recommendations to safeguard international civil aviation against acts of unlawful interference are listed in ICAO Annex 17 to the Convention on International Civil Aviation. Suggested security measures and procedures are amplified in the ICAO Security Manual for Safeguarding Civil Aviation Against Acts of Unlawful Interference.

Annex 17 requires contracting States of which Canada is one to "take the necessary measures to prevent weapons or any other dangerous devices, the carriage or bearing of which is not authorized, from being introduced by any means whatsoever, on board an aircraft engaged in the carriage of passengers."

In addition to other recommendations, Annex 17 recommends that contracting States should establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage, cargo, mail and stores to be carried on board aircraft.

The Security Manual specifies that, for the security processing of passengers and goods for special risk flights, the following measures should be considered:

- Operators should develop procedures which ensure that only baggage of passengers actually travelling on the flight and previously security-processed unaccompanied baggage is loaded on the aircraft. This will entail the necessity for correlating passengers who check in baggage with passengers boarding the aircraft.

- The suspension of check-in baggage at any point other than the operator's check-in counter.

- Strict control should be exercised over tags used to identify cabin and checked/hold baggage so as to ensure that such baggage does not by-pass the inspection/screening process.

- Passengers and crew members may be required to personally identify their hold baggage before it is loaded on the aircraft; any unidentified baggage should not be loaded.

- When greater security is required, it is particularly important that the number of passengers on an aircraft coincide with the number of boarding passes issued. This check must ensure that all passengers in transit on the same flight who leave the aircraft reboard it; that only passengers board the aircraft; and that passengers terminating their journey at that stop do not reboard the aircraft.

- Special precautions should be taken to control transfer and transit passengers and baggage, including the surveillance of transit areas (arrival/departure halls) and baggage storage and sorting areas.

- In some circumstances, all passengers may be required to leave the aircraft, all hand baggage and personal effects removed, and the aircraft interior searched.

- There should be inspection/screening of all items such as flight document bags, catering supplies, duty-free purchases, etc., before they are placed on board the aircraft.

- There should be close surveillance of passengers and baggage moving between aircraft and terminal buildings, and also the movement of interline baggage.

- The general practice of States is to limit the inspection/screening of checked/hold baggage to the application of special security measures to specific flights as covered by the provisions of Annex 17. This procedure is only applied upon the request of a State or an operator.

The Security Manual further states that diplomatic pouches are exempt from manual search in accordance with Article 27, paragraph 3, of the Vienna Convention on Diplomatic Relations; however, there is no general agreement among States whether the provisions of the Convention apply to the inspection/screening of such items by an X-ray device.

Recently, ICAO has proposed amendments to Annex 17. These proposals arise from a decision taken by the Council in its 115th Session on 10 July 1985. The Council instructed its Committee on Unlawful Interference, as a matter of urgency, to review the entirety of Annex 17 and to report on those provisions which might be immediately introduced, upgraded to Standards, strengthened or improved. Among the proposed amendments is the following upgrading in the Standards:

- Each contracting State ensure the implementation of measures at airports to protect cargo, baggage, mail stores and operator's supplies being moved within an airport to safeguard such aircraft against an act of unlawful interference.

2.5 Canadian Law

In terms of Canadian statutory requirements, the Civil Aviation Security Measures Regulations and the Foreign Aircraft Security Measures Regulations made pursuant to the Aeronautics Act require specified owners or operators of aircraft registered in Canada or specified owners or operators who land foreign aircraft in Canada to establish, maintain, and carry out security measures at airports consisting of:

- systems of surveillance of persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;

- systems of searching persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;

- a system that provides, at airports where facilities are available, for locked, closed or restricted areas that are inaccessible to any person other than a person who has been searched and the personnel of the owner or operator;

- a system that provides, at airports where facilities are available, for check-points at which persons intending to board the aircraft of an owner or operator can be searched;

- a system that provides, at airports where facilities are available, for locked, closed or restricted areas in which cargo, goods and baggage that have been checked for loading on aircraft are inaccessible to persons other than those persons authorized by the owner or operator to have access to those areas;

- a system of identification that prevents baggage, goods and cargo from being placed on board the aircraft if it is not authorized to be placed on board by the owner or operator; and

- a system of identification of surveillance and search personnel and the personnel of the owner or operator.

Specified carriers including Air Canada, CP Air, and Air India were required to provide a description of their security measures to the Canadian Minister of Transport.

An Order-in-Council on 29 September 1960 established that the RCMP was responsible for the direction and administration of police functions at major airports operated by Transport Canada. The duties of the Police and Security Detail at these designated airports include the following:

- carry out policing and security duties to guard against unauthorized entry, sabotage, theft, fire or damage;

- enforce federal legislation;

- respond to violations of the Criminal Code of Canada, Federal, Provincial, and Territorial statutes, and perform a holding action pending arrival of the police department having primary criminal jurisdiction;

- man guard posts; and

- provide a police response in those areas of airports where pre-board screening takes place.

Section 5.1(9) of the Aeronautics Act states that "The Minister may designate as security officers for the purposes of this section any persons or classes of persons who, in his opinion, are qualified to be so designated." Pursuant to this section Transport Canada has established criteria for persons or classes of persons that are designated as security officers in a Schedule registered on 11 April 1984. The criteria also specify that a security guard company and its employees will meet Transport Canada requirements provided that the company:

- is under contract with a carrier to conduct passenger screening under the Aeronautics Act and Regulations;

- is licensed in the province or territory;

- complies with the security guard criteria as follows in that the guard must:

  - be 18 years or older,
  - be in good general health without physical defects or abnormalities which would interfere with the performance of duties,
  - be licensed as a security guard and in possession of the licence while on duty, and
  - meet the training standards of Transport Canada consisting of successfully completing the Transport Canada passenger inspection training program, attaining an average mark of 70 per cent, and undergoing refresher training within 12 months from previous training;

- uses a comprehensive training program which has been approved by Transport Canada and is capable of being monitored and evaluated;

- keeps records showing the date each employee received initial training and/or refresher training and the mark attained; and

- provides supervision to ensure that their employees maintain competency and act responsibly in the conduct of searching passengers and carry-on baggage being carried aboard aircraft.

2.6 Canadian Security Procedures

In accordance with the Canadian Aeronautics Act and pursuant regulations, air carriers are assigned the responsibility for security. Transport Canada provides the following security services for the air carriers using major Canadian airports, including the international airports in Vancouver, Toronto and Montreal:

- security and policing staff including RCMP airport detachments;

- specific airport security plans and procedures;

- secure facilities (e.g., secure areas, pass identification systems, etc.); and

- security equipment and facilities (e.g., X-ray detection units, walk-through metal detectors, hand-held metal detectors, explosive detection dogs).

As of 22 June 1985, the following general security measures were in place at Canadian airports:

- metal detection screening of passengers; and

- X-raying of carry-on baggage.

Checked baggage was not normally subject to any security screening. A few air carriers such as Air India had extra security measures in place because of an assessed higher threat level (see section 2.7 below).

On 23 June 1985, Transport Canada required additional security measures to be implemented by all Canadian and foreign air carriers for all international flights from Canada except those to the continental United States. These measures required:

- the physical inspection or X-ray inspection of all checked baggage;

- the full screening of all passengers and carry-on baggage; and

- a 24-hour hold on cargo except perishables received from a known shipper unless a physical search or X-ray inspection is completed.

Further, on 29 June 1985, Transport Canada directed that all baggage or cargo being interlined within Canada to an Air India flight was to be physically inspected or X-rayed at the point of first departure and that matching of passengers to tickets was to be verified prior to departure.

2.7 Air India Security Program in Canada

In accordance with the Foreign Aircraft Security Measures Regulations, Air India had provided the Minister of Transport with a copy of its security program. It included measures to:

- establish sterile areas;

- physically inspect all carry-on baggage by means of hand-held devices or X-ray equipment;

- control boarding passes;
- maintain aircraft security;
- ensure baggage and cargo security; and
- off-load baggage of passengers who fail to board flights.

Under these procedures established by Air India, passengers, carry-on baggage, and checked baggage destined for AI 181/182 on 22 June 1985 were subjected to extra security checks. A security officer from the Air India New York office arrived in Toronto on 22 June 1985 to oversee the security operation at Toronto and Montreal.

On 17 May 1985, the High Commission of India presented a diplomatic note to the Department of External Affairs regarding the threat to Indian diplomatic missions or Air India aircraft by extremist elements. Subsequently, in early June, Air India forwarded a request for "full and strict security coverage and any other appropriate security measures" to Transport Canada offices in Ottawa, Montreal and Toronto, and RCMP offices in Montreal and Toronto.

2.8 PD-4 Sniffer

On 18 January 1985, prior to the inaugural Air India flight out of Toronto on 19 January, a meeting on security for Air India flights (Toronto) was held with representatives from Transport Canada, RCMP and Air India. At this meeting, a PD-4 sniffer belonging to Air India was produced. It was explained that it would be used to screen checked baggage as the X-ray machine had not yet arrived. At that time, an RCMP member tested its effectiveness. The test revealed that it could not detect a small container of gunpowder until the head of the sniffer was moved to less than an inch from the gunpowder. Also, the next day the sniffer was tried on a piece of C4 plastic explosives and it did not function even when it came directly in contact with the explosive substance. It is not known if this was the same sniffer used on 22 June 1985.

2.9 Medical Evidence

Medical examination was conducted on the 131 bodies recovered after the accident. This comprises about 40 per cent of the 329 persons on board. It should be noted that assigned seating is based on preliminary information. Also, the exact position of passengers is not certain because it is not known if passengers changed their seats after lift-off. On the information available, the passengers were seated as follows:

Passengers:*

	Seats Available	Occupied	Bodies Identified
Zone A	16	1	0
Zone B	22	0	0
Upper Deck	18	7	0
Zone C	112	104 + 2	29
Zone D	86	84 + 1	38
Zone E	123	105 + 3	50
SUB-TOTAL	377	301(+6 infants)	117
Crew:			
Flight Deck	3	3	0
Cabin	19	19	5
TOTAL	399	329	122

There were 30 children recovered and they showed less overall injury. The average severity of injury increases from Zone C to E and is significantly less in C than in Zones D and E.

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. They were evenly

*See Appendix C for interior seating arrangement.

distributed throughout the zones, but with a tendency to be seated at the sides, particularly the right side (12 bodies).

Twenty-three bodies showed evidence of receiving injuries from a vertical force. They tended to be older, seated to the rear of the aircraft (4 in Zone C, 5 in Zone D, 11 in Zone E, 2 crew and 1 unknown), and 16 had little or no clothing.

Twenty-one bodies were found with no clothing, including three children. They tended to be seated to the rear and to the right (3 in Zone C, 5 in Zone D, 11 in Zone E and 2 unknown).

There were 49 cases showing signs of impact-type injuries, including 19 children (15 in Zone C, 15 in Zone D, 15 in Zone E, 1 crew member and 3 unknown).

There is a general absence of signs indicating the wearing of lap belts.

Pathological examination failed to reveal any injuries indicative of a fire or explosion.

2.10 Flight Recorders and Shannon Air Traffic Control (ATC) Tape Analyses

VT-EFO was equipped with a Fairchild A100 Cockpit Voice Recorder (CVR) and a Lockheed 209E Digital Flight Data Recorder (DFDR). These were each equipped with Dukane Underwater Acoustic Beacons and were installed adjacent to each other in the cabin on the left side near the aft pressure bulkhead. The serial digital signal recorded by the DFDR was generated by a Teledyne Flight Data Acquisition Unit installed in the forward electronics bay below the cabin floor.

The Shannon Air Traffic Control Centre was in contact with VT-EFO and recorded radio communications with the aircraft. At the time of the accident, 5.4 seconds of noise was recorded, and the transponder signal seen on the radar scope was lost from the aircraft. This signal which displays aircraft altitude showed no deviation before disappearing from the radar scope.

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. The initial waveform of the cockpit area microphone signal is not consistent with the sharp pressure rise expected with detonation of an explosive device close to the flight deck, but, with the multiplicity of paths by which sound may be conducted from other regions of the aircraft, the possibility that it originated from such a device elsewhere in the aircraft cannot be excluded.

By correlating the oscillograph records of the CVR and the Shannon ATC VHF recording, it was estimated that the unusual sounds recorded on the ATC tape started 1.4 $\pm$ 0.5 seconds after the start of the sudden sound detected by the cockpit area microphone and lasted intermittently for 5.4 seconds. It was felt the closeness in time of the two noises indicated the 5.4 seconds recorded on the ATC tapes originated from AI 182. The ATC recording that followed the cockpit area microphone sounds appeared at first to contain a series of short intermittent sounds. Listening to the sounds, it also appeared that a human cry occurred near the end of the recording. Spectral analysis of these sounds and comparison with voice imitations revealed that the recorded sounds do not contain all the pitch harmonic frequencies normally associated with voice sounds. The origin of these sounds has not been determined.

An examination of the DFDR showed no abnormal variations before the accident. With the spare engine, this aircraft was restricted to altitudes below 35,200 feet and indicated airspeeds less than 290 knots. During the last 27 minutes of the flight, the computed airspeed did gradually increase to nine knots above this limit in the first part of this period and the power was readjusted several times. The speed fell below the 290 knot limit at about 07h:09m GMT as recorded by the DFDR; power was increased again at about 07h:10m causing the aircraft to

accelerate to six knots above the limit by the time the accident occurred at 07h:13m:59s. The observed excursions outside the specified limits are not considered significant.

The aircraft was flown with 1.5-degree left-wing-down with 4.2 degrees clockwise control wheel as compared to the aircraft without the 5th engine installation. Also, 9.4 per cent of right rudder pedal was applied giving a 1.1-degree right deflection of the upper and lower rudders. Considering the carriage of the 5th engine on the left side, these figures are not considered abnormal.

When synchronized with the other recordings, it was determined, within the accuracy that the procedure permitted, that the DFDR stopped recording simultaneously with the CVR.

Irregular signals were observed over the last 0.27 inches of the DFDR tape. Laboratory tests indicated that the irregular signals most likely occurred as a result of the recorder being subjected to sharp angular accelerations about the lateral axis of the recorder, causing rapid changes in tape speed over the record head. This equates to an angular acceleration on the recorder about the aircraft's longitudinal axis in a left-wing-down sense. Therefore, these tests indicate that the digital recorder was subjected to a sharp jolt separate from any violent motion of the aircraft.

The other possibility for the irregular signals is that the Flight Data Acquisition Unit which generated the serial digital data signal and which is located in the electronics bay under the cabin floor forward of the cargo compartment could have suffered some damage or had an intermittent power supply that caused it to generate the irregular signals.

2.10.2 Analysis by Accidents Investigation Branch (AIB), United Kingdom

The AIB analysis was restricted to the CVR and the Shannon ATC tape. The correlation of the CVR and ATC tapes showed that the ATC recording started after the CVR had stopped recording and 1.1 + 0.4 seconds from the start of the

sudden sound. The total duration of the signal on the ATC tape was 5.4 seconds.

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. Evidence of the presence of audio warning signals buried amongst the noise was investigated with negative results. A comparison with CVRs recording an explosive decompression* on a DC-10, a bomb in the cargo hold of a B737, and a gun shot on the flight deck of a B737 was made. 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.

The analysis of the ATC tape audio determined three or four words could be heard at the beginning of the transmission, but extensive filtering did not allow the sounds to be transcribed. Two bursts of tone occurred during the first second. The spectrum of the tone does not coincide with any B747 audio warning. The transmission is chopped until at about 2.7 seconds into the transmission a loud noise lasting about 200 milliseconds is heard. This is followed about 0.5 seconds later by a sound which increases in volume. This sound is similar to that heard in other accidents where there has been a rapid increase in airspeed. Toward the end of the transmission a crying sound was heard; however, a study of the noise indicates a human cry would contain more harmonics. The origin of this sound was not determined. Knocking sounds were also heard during the transmission. These were initially thought to be due to hand-held microphone vibration, but this was discounted because of the frequency of the sounds. Almost identical sounds were heard on the DC-10 CVR after the explosive decompression had occurred. Their source was not identified. On the DC-10, the pressurization audio warning sounded 2.2 seconds after the decompression. No such warning was identified on the ATC tape.

*Explosive decompression is an aviation term used to mean a sudden and rapid loss of cabin pressurization. A loud noise is associated with this event but not necessarily an explosion.

Every aircraft provides a different signature when the press-to-transmit button is released. These signatures were compared with transients which occurred during the open microphone transmission. There is a close match with the previous AI 182 signatures. Therefore, it is almost certain that the ATC tape recording originated from AI 182.

The AIB report concluded that the analysis of the CVR and ATC recordings showed no evidence of a high-explosive device having been detonated on AI 182. It further states there is strong evidence to suggest a sudden explosive decompression of undetermined origin occurred. Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone. However, the AIB report is of the opinion that the device would have to be small not to be detected as it is considered that a large high-explosive device could not fail to be detected on the CVR.

2.10.3 Analysis by Bhabha Atomic Research Centre (BARC), India

The BARC analysis was restricted to the CVR and the Shannon ATC tape.

Channel 3 of the recording which corresponded to the cockpit area microphone showed the first indication of a rising audio signal. The signal level rises from the ambient level in the cockpit by about 18.5 decibels in approximately 45 milliseconds. The signal starts falling and stabilizes at a level about 10 decibels higher than ambient for about 375 milliseconds. The total duration of the signal is about 460 milliseconds.

The timings of the CVR and the Shannon ATC tape were correlated, and it was determined that the explosive sound on the CVR coincided with the beginning of the series of audio bursts on the ATC tape. The report concluded that the sounds recorded on the ATC tape emanated from AI 182 at the time of the occurrence.

The noise on the CVR was compared with an explosion which caused the crash of an Indian Airlines B737. In this occurrence, the explosive sound recorded on the cockpit

area microphone showed a rise time of about 8 milliseconds. It was also determined that the explosion occurred 8 feet from the microphone. The report concluded that the rise time is a measure of the distance from the cockpit area microphone to the source of an explosion. Hence, the exact location in the aircraft at which the explosion occurred is likely to be about 40 to 50 feet from the cockpit judging from the rise time of 45 milliseconds.

The report concluded that the series of audio bursts on the ATC tape were most probably generated by the break-up of AI 182 in mid-air.

2.11 Aircraft Structures Examination

The examination of aircraft structures consisted of the following areas: floating wreckage, wreckage mapping and surveying, wreckage distribution, photographic and video interpretation of wreckage, wreckage recovery and initial examination, and examination of recovered wreckage.

2.11.1 Floating Wreckage

During the search, aircraft wreckage was sited and recovered by several search vessels. The wreckage was transported to Cork, Ireland, where preliminary examination was conducted. This examination took place in June and July, 1985.

The wreckage consisted mainly of various leading edge skin panels of the left and right wings, left wing tip, spoilers, leading edge and trailing edge flaps, engine cowlings, flap track canoe fairing pieces, landing gear wheel well doors, pieces of elevator and aileron, cabin floor panels, cabin overhead and upper deck bins, passenger seats, life vests, slide rafts, hand baggage, suitcases, personal effects and a number of internal fittings. The floating wreckage constitutes about three to five percent of the aircraft structure.

The wreckage was then transported from Ireland to Bombay, India where it underwent further examination by the Floating Wreckage Structures Group which then

produced a report which was submitted to the Indian Inquiry. The report concluded:

- There was no evidence of fire damage.

- There was no evidence of lightning strike damage.

- The cabin floor panels from the forward and rear sections of the aircraft separated from the support structure in an upward direction (floor to ceiling) pulling free from the attaching screws and, in some cases, breaking the vertical web of the seat track/floor beams.

- The position of the leading edge flap rotary actuator and the damage to the flap structure indicated that the leading edge flaps were in the retracted position.

- The six spoiler actuators found were in the retracted position. The lower surface of all the spoiler panels showed signs of spanwise skin splits with the edges curled into the core of the honeycomb. The report concluded that this was possibly due to the loading of the spoilers by being deployed in flight at high speed, resulting in compression on the lower surfaces. This, in turn, caused splitting of the lower skin into the honeycomb.

- The right wing root leading edge, number 3 engine inboard fan cowling, the right inboard midflap inboard leading edge, and the right stabilizer root leading edge all exhibited damage possibly due to objects striking the right wing and stabilizer before water impact.

In addition to the above conclusions, the following significant information regarding the floating wreckage is noted in the report:

- The aircraft was carrying a -7Q engine at the 5th pod and a -7J 5th pod kit in the aft cargo compartment. In all there were 14 engine fan cowls (four in the aft cargo compartment). Out of these 14 fan cowls, nine, including six from the working

engines and three from the aft cargo compartment, and two additional pieces of fan cowls were found. Five of the fan cowls from the working engines showed folding damage lines at about the three and nine o'clock positions. The number 3 engine inboard fan cowl had severe impact damage on its leading edge and had small outward puncture holes but no penetration through the outer skin in the lower centre region. The two fan cowls of the -7J 5th pod kit stowed in the aft cargo compartment showed severe damage. One piece was cut at one corner in an arc of about 20 inches diameter and its external skin was peeled back.

- The cockpit entry door and the side bulkhead panel were found relatively intact but had come out of their attachments.

- Twelve toilet doors out of 16 were found and were relatively intact but had come out of their attachments.

- Cabin interior panels and overhead bins of the main and upper decks which were recovered exhibited only minor damage.

- The wooden boxes which contained the fan blades of the 5th pod engine were loaded in container 24L in the forward cargo compartment and were found broken apart exhibiting no burn marks.

- One passenger oxygen bottle and one portable oxygen bottle were recovered and showed no sign of damage.

Mr. V.J. Clancy, an aviation explosives expert representing Boeing Aircraft Corporation, prepared a preliminary report based on his examinations of certain items of recovered and floating wreckage. Mr. Clancy's report notes the following with respect to floating wreckage:

- A foam-backed floor panel which showed a small number of perforations was recovered. Mr. Clancy recommended that it should be X-rayed and a detailed examination completed.

- One of the lavatory doors had, into its inner surface, a number of fragments of glass mirror - presumably from breakage of a mirror normally fitted into the lavatory. Most of the fragments, buried edgeways, were oriented parallel to each other. The remainder were approximately at right angles to the others. Mr. Clancy concluded that it would be improbable that any reliance could be placed on the penetration by mirror fragments as being indicative of an explosion.

- Three steel oxygen cylinders which were stowed in the forward cargo compartment were recovered. One had been dented apparently by the impact of an object measuring about one to two centimetres. The depression had a maximum depth of about four millimetres.

- A few suitcases recovered among the floating wreckage were examined. Mr. Clancy felt that one might provide useful information. It was of red plastic material with a blue lining. Mr. Clancy reported that plastic material has been found to retain identifiable traces of explosive after long immersion in the sea. Also, the lining which was severely tattered resembled that of one found after an explosion in an aircraft in Angola.

- A wooden spares box was found on the foreshore of Wales. It was of the kind used on the aircraft. It was charred on one side and partially on the bottom. The depth of charring suggested that the burn time was three to four minutes. This box was normally stowed in the aft cargo compartment; however, on this flight it may have been stowed in the forward compartment.

- Two pieces of the cover of an overhead locker originating above either door 2R or 4R were also found on the foreshore. They were partially damaged and blackened by fire. Mr. Clancy concluded that this indicated the presence of fire.

- Two pieces of U-section alloy channel partially filled with plastic foam were found on the foreshore. The alloy was of a kind not used in

aircraft structure; however, it could have been from some fitting supplied by a sub-contractor. Also, since the pieces were found near an area where practice firings at targets are carried out off the west coast of the United Kingdom, it could have come from some other source. One piece of the alloy bore marks ("mooncraters") typical of an attack by very high velocity fragments such as produced by an explosion. X-rays showed the presence of a few small particles buried in the foam which Mr. Clancy recommended should be extracted and examined. He also felt that this provided the strongest single indication of an explosion and that it was essential to determine if these pieces came from the aircraft or any of the equipment or cargo aboard the aircraft.

The CASB in its examination of the floating wreckage noted the following:

- 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.

- The upper deck storage cabinet which was located on the left side had unusual damage to its bottom. A large rounded dent in the bottom inboard edge of this stiff cabinet structure revealed smooth stretching without breakthrough. The damage did not seem to be achievable by inertia or impact forces as the cabinet except for the bottom was undamaged. The damage was considered by a CASB investigator to be compatible with the spherical front of an explosive shock wave generated below the cabin floor and inboard from the cabinet; however, it is not known if this damage could be caused by some other means.

- The right wing root fillet which faired the leading edge of the wing to the fuselage ahead of the front 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. The paint on the inboard chord appeared to be scorched brown in the centre areas of three honeycomb panels. It has been determined that sudden heat can turn these panels brown, but it is not known if other reasons for the discolouration exist. The fillet abutted the fuselage side at the aft end of the forward cargo compartment.

- There was blackened erosion damage to the bottoms of some seat cushions. The damage had an appearance similar to that which would have been caused by an explosive device. It is not known if marine life feeding on the cushions or some other cause could have produced the same effect.

- The charred wooden spares box contained some sand and small shellfish. The flesh from the shellfish appeared to be charred, indicating that the box was subjected to fire after the occurrence.

An electronic device was found among some floating wreckage and was forwarded to the Bhabha Atomic Research Centre for analysis. There was some concern that it could have been used to detonate an explosive device. The device was forwarded to the RCMP who in conjunction with the CASB determined it to be an item manufactured for use in radiosondes (weather balloons) and was not modified as a detonating device.

2.11.2 Wreckage Mapping and Surveying

The Canadian Coast Guard Ship (CCGS) John Cabot was given the task of mapping the wreckage on the ocean floor. On 19 July 1985, the Cabot with a SCARAB deep submersible on board departed Cork. On arrival at the site, and based on surface wreckage distribution and bottom side scan sonar plots, four transmitters were placed on the sea bed. These transmitters provided signals for the ALLNAV navigation system used to accurately plot the sea bed wreckage.

Based on all the data available, the SCARAB was launched on 24 July 1985 to begin the bottom search in position 51°01.9'N 12°41.0'W. During the mapping,

stage areas were designated for search and each progressive area was determined based on the information gained during the search. The search was conducted using sonar and video. Wreckage found was recorded on video tape and on 35mm positive film.

The first object plotted on the sea bed was a torn suitcase located at lat 51°02.63'N, long 12°53.15'W and was the most westerly object located. This suitcase has not been recovered, nor has it been positively identified as having come from the accident aircraft.

As the search progressed eastward, the first positive identification of aircraft wreckage was made at lat 51°02.9'N, long 12°49.93'W. Slowly, over a period of about 90 days, a detailed bottom wreckage plot was developed.

While mapping was in progress, some of the wreckage was revisited to obtain additional data. During the transit through areas already searched, wreckage not previously plotted was found, and, in some areas, the density of wreckage physically precluded 100 per cent coverage. Components and major structural items were identified from all sections of the aircraft and when the mapping of the sea bed ended, most of the aircraft had been found and photographed. Although positive identification of each piece of wreckage could not be made, it was decided in late October 1985 that the search phase was essentially completed and wreckage recovery could begin. A bottom wreckage distribution plot is contained separately in an envelope as Appendix F.

2.11.3 Wreckage Distribution

The wreckage distribution as determined by the mapping of the sea bed provided some distinct distribution patterns. The depth of the wreckage varies between about 6000 and 7000 feet, and the effect of the ocean current, tides and the way objects may have descended to the sea bed was not determined, thus some distortion of an object's relationship from time of water entry to its location on the bottom cannot be discounted. In general, the items found east of long 12°43.00'W are small, lightweight and often made of a structure which

traps air. These items may have taken considerable time to sink and may have moved horizontally in sea currents before settling on the bottom. Marks left on the sea bed beside some wreckage does indicate horizontal movement of the wreckage as it settled.

Although badly damaged, sections 41, 42 and 44*, and the wing structure were located in a relatively localized area centred about lat 51°03.30'N and long 12°47.80'W, and the wreckage scatter was oriented north/south. The wreckage scatter in this area was so dense that it is probable that some of the wreckage may not have been plotted or photographed.

Sections 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern with the westernmost identified aircraft component located at lat 51°02.90'N and long 12°50.1'W. The wreckage extended in a line about 110 degrees True to an eastern position of lat 51°02.04'N and long 12°41.26'W, a distance of approximately 6.5 nautical miles. The aircraft structure had a random scatter pattern. That is, items such as the aft pressure bulkhead were broken into several pieces, and these pieces were located throughout the pattern.

A third area which had some distinctive pattern was that of the engines, engine struts and components and was localized about lat 51°03.25'N and long 12°47.4'W in a northwest/southeast orientation. One of the operating engines was displaced 0.5 nautical miles to the north of this area, and it was also geographically separated from the wing structure. The number 3 engine nacelle strut was also separated from the rest of the engine components and was located about one nautical mile to the west-southwest at lat 51°02.87'N, long 12°48.05'W. The reasons for the displacement of the number 3 engine nacelle strut and one of the operating engines from the other engines are not known.

*See Appendix D for location of aircraft sections and aircraft body stations (BS).

2.11.4 Photographic and Video Interpretation of Wreckage

2.11.4.1 Photographic Interpretation

All wreckage sighted was recorded on video tape and all major items were recorded on 35mm positive film. During the course of the investigation, several members of the investigation team had the opportunity to view the tapes and photographs. Subsequently, when some items were recovered, it became apparent that the optical image presented on video and still film had some limitation with respect to identification of damage or damage patterns. For example, the sine wave bending of target 7* appeared in the video and photographs as a sine wave fracture, and some of the buckling on target 35 was not evident in either the video or photographs. The interpretation of damage through photographic/video evidence without the physical evidence might be misleading, and any interpretation should take this into account.

2.11.4.2 Engines

The four operating engines were all extensively damaged. A view of the fan blades did not show signs of any rotational damage, and it could not be determined whether any pre-impact failures had occurred. The external damage to the engines varied, and at least one engine appeared to be attached to part of the nacelle strut. Except for the non-operational fifth engine, the engines could not be matched with their original positions on the aircraft.

2.11.4.3 Landing Gear

The nose, wing, and body landing gear were all located. Photographic examination indicated that all the gear were in the 'up' position at the time of impact.

2.11.4.4 Flaps and Spoilers

Positive identification of all the flap and spoiler surfaces was not made. All the flap jackscrews indicated that the flaps were retracted at impact. Of

*See Appendix E for location of targets on aircraft.

the spoilers identified, six had actuators attached. The actuators were in the fully retracted position.

2.11.4.5 Section 41

Section 41, consisting of the cockpit, first-class section, and electronics bay and identified as target 192, was found in a near-inverted attitude. This section was severely damaged. The electronics bay and cockpit areas could not be located within the wreckage. The first officer's seat was found on the sea bed near section 41 wreckage.

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. 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.

2.11.4.7 Section 44

Section 44, containing the aircraft structure between body station (BS) 1000 and BS 1480 including that area where the fuselage and wings were mated was located in the same general area as the forward sections of the aircraft. This section was severely damaged but maintained its overall shape and was lying on its right side. Part of the left wing upper skin was attached to the fuselage and a large portion, about one-third of the upper wing skin, separated and was lying against the fuselage crown skin. Some of the body and wing landing gear were found beside this section of the aircraft. The gear was detached from the main structure. The interior of the fuselage was extensively damaged.

2.11.4.8 Wing Structure

The wing structure was located near the forward area of the aircraft structure and towards the northernmost area of the wreckage pattern. The wings showed extreme damage patterns with the top and bottom surfaces separated and the wing surfaces broken into segments.

2.11.4.9 Sections 46 and 48

Sections 46 and 48 contain that part of the aircraft structure aft of BS 1480 and, for purposes of this Submission, will include the horizontal stabilizer and vertical fin. This section of the aircraft was scattered in a west to east pattern about 6.5 nautical miles in length and exhibited severe break-up characteristics.

The aft cargo and bulk cargo doors were found in place and intact, and 5L, 5R and 4R entry doors were identified. Four segments of the aft pressure bulkhead were identified (targets 35, 37, 73 and 296), and one portion of the bulkhead was never located. Much of the fuselage which was forward of the number five door and above the passenger floor area was not located, or if located was not recognizable as having come from a specific area of the aircraft.

Sections of the outer skin below the cargo area were located as was some of the cargo floor structure. Generally, the stringers and stiffeners are attached to the skin; however, the lower frames, which provided the cargo floor support, were detached from the skin. The rear cargo floor from BS 1600 to BS 1760 was located and was found to have little or no distortion; however, the lower skin and stringers were missing. A second portion of the aft cargo compartment floor containing cargo drive wheels and cargo roller trays was located. This structure was severely damaged and mangled.

The tail cone and the auxiliary power unit (APU) housing were located and had received relatively minor damage; however, the APU had broken free and was never located.

A large portion of the outer skin panels showed signs of a force being applied from the inside out. On several pieces of wreckage, the skin was curled outwards away from the stringers and formers. This could have been the result of an overpressure of air or water.

The vertical tail was found in good condition, in a single piece with both rudders attached. The top cap was partially separated and a small dent was noticed in the middle of the leading edge at the bottom. A curved broken portion of fuselage was observed with a portion of the "Y" ring and pressure bulkhead attached. Another small segment of the pressure bulkhead was leaning on the lower section of the tail.

The horizontal stabilizer tail section was located and was one unit with the elevators attached. The actuator jackscrew was attached to the assembly. The stabilizer jackscrew ballnut was observed to be located at the upper jackscrew stop. This equates to a full deflection of elevator trim. Since there is nothing on the DFDR or CVR to indicate a malfunction of the trim, it is deduced that this was not the lead event. It is not known if the position of the ballnut resulted from a pilot trim selection, a result of the initial event or if it rotated to the observed position under the influence of gravity. Two-thirds of the leading edge of the right horizontal stabilizer was missing and the

auxiliary spar was exposed. There was localized damage to the right-hand root of the leading edge through about a span of five ribs. The leading edge skin and part of the leading edge ribs were torn downwards. Some localized damage to the root of the left leading edge was visible with the remainder of the leading edge undamaged. There was minor damage to the trailing edge of the outboard left elevator, and a major portion of the inboard left elevator was missing.

2.11.4.10 Passenger Seats

Many of the passenger seats located among the wreckage pattern and identified as having come from sections 46 and 48 appeared to have the aft support legs buckled with little or no damage to the forward support legs. Seats located in the wreckage containing sections 41, 42, and 44 appeared to have varying types of damage, that is, aft support legs only buckled, and all legs buckled. One consistent feature noted was that in the majority of seats located it was possible to ascertain that the seat-belts were not fastened.

2.11.5 Wreckage Recovery and Initial Examination

During the wreckage mapping, some small items were recovered, and an unsuccessful attempt was made to recover a portion of the forward cargo door. On completion of the sea bed survey, an offshore supply ship, Kreuztrum, chartered by the National Transportation Safety Board (NTSB), joined John Cabot for a wreckage recovery operation. Prior to the commencement of the wreckage recovery, the structures group met at the Boeing facility in Seattle, USA and reviewed the video tapes and photographs of the wreckage. Based on their findings, a list of items was identified as being most desirable for recovery. The priority list was prepared by a group in Cork, Ireland, headed by Dr. V. Ramachandran. On 8 October 1985, the John Cabot sailed, and on 9 October 1985, the Kreuztrum sailed for the accident site. The following target numbers and items were recovered during the mapping and wreckage recovery stages of the investigation: 7, 8, 35, 47, 117, 193, 223, 245, 287, 296, 299, 362/396, and 399 (as the location on the aircraft of some of the targets was not known when Appendix E was created, some

are not shown in the appendix). The first officer's seat, some suitcases and small debris were also recovered using a metal frame basket. Initial examination of the wreckage was carried out in Cork and then it was transported to Bombay for detailed examination.

2.11.6 Examination of Recovered Wreckage

Although all the recovered wreckage was examined, only those items exhibiting characteristics which provided some evidence as to what may have happened to the aircraft during its final moments of flight are discussed. CASB engineering personnel and other participants examined the recovered wreckage at Cork and Bombay. The observations made during their examinations are discussed below.

2.11.6.1 Target 7 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and contained the keel beam. Target 7 extended from BS 1480 to 1860 and was about eight feet in width and 32 feet in length. The left edge had a full length rivet line tear, and the torn edge was buckled in waves, like the trace of a sine wave. On the right side, between the one-quarter and midway segment, a large flap of skin was attached. The skin was folded aft, diagonally underneath, from right to left and the paint was scoured off the leading edge. The forward break was at the joint at BS 1480. The skin tear located at about BS 1860 was irregular in nature. The forward keel joint splice plate was bent, and the keel joint bolt holes were distorted and elongated.

The left and right trunnion vertical support fittings located at BS 1480 were examined optically using the stereomicroscope. Both trunnions were fractured through the three bolt holes. The right fracture characteristics were consistent with an overload mode of failure. Although most of the left fracture surface was also characterized by overload features, there were heavily corroded areas where the fracture mode could not be confirmed through optical examination. One lug fracture was sectioned from the left trunnion and prepared for scanning electron microscope (SEM)

examination. After the corroded area was cleaned, the examination revealed some ductile characteristics on the fracture surface. There was no evidence of intergranular fracture observed to suggest a stress corrosion cracking mode of failure, nor was there any evidence of progressive failure observed. The corrosion appeared to have developed after the accident.

2.11.6.2 Target 8 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and extended from BS 1860 to 1960 and from stringer 46L to 46R. A small section from the aft end along the belly skin splice at stringer 46L was removed for examination. SEM examination revealed that the fracture was characterized by slightly elongated ductile dimples along its length, including areas adjacent to the edges of the rivet holes. On the aft edge of each rivet hole examined, a distinctive shear lip was observed. These features are consistent with an overload mode of failure along the skin splice with an apparent direction of failure from aft to forward.

2.11.6.3 Target 35 - Portion of Rear Pressure Bulkhead

Looking forward from behind the aircraft, this segment of pressure bulkhead occupied the 9 to 1 o'clock position. The piece from 12 to 1 o'clock had the flange from the outer ring attached. The web below the outer ring flange had areas of buckling. From the 11 to 12 o'clock position, the outer edge showed sinusoidal buckling, and the edge sector at 9 o'clock was partially collapsed and its edge was turned under. Samples taken for optical stereomicroscope and SEM examination revealed that the fracture characteristics were consistent with an overload mode of failure. The examination suggested a general direction of failure from the aft to the forward edge of the rear pressure bulkhead panel.

2.11.6.4 Target 296 - Portion of Rear Pressure Bulkhead

Looking forward from the rear of the aircraft, this segment of the bulkhead occupied the 7 to 9 o'clock

position. Optical and SEM examination were undertaken on this item.

The fracture along the left-hand edge of target 296 (viewed from the rear) was examined optically prior to removing any representative samples. The fracture was at the rivet line at a skin splice, except for a length of fracture about 15 inches long near the forward end, which was through the skin away from the rivet line. Most of the rivet holes along the fracture path showed some slight elongation and skin deformation.

Representative fracture samples were cut from the left-hand and right-hand edges of the fracture surfaces. Optical and SEM examination revealed that the fracture characteristics are consistent with an overload mode of failure.

2.11.6.5 Target 47 - Aft Cargo Compartment

This portion of the aft cargo compartment roller floor was located between BS 1600 and BS 1760. Based on the direction of cleat rotation on the skin panel (target 7) and the crossbeam displacement on this structure, target 47 moved aft in relation to the lower skin panel when it was detached from the lower skin. No other significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

2.11.6.6 Target 117 - Floor with Seats Attached

These seats were right-section doubles, located between BS 1880 and 1980 and were from rows 46, 47 and 48, F and G (Zone E). The seats were displaced to the left with the rear legs buckled to the left. The front leg supports exhibited only minor damage. The middle and rear doubles had aisle-side seat arms bent to the right. There was no impact damage to the seat backs or seat pans, and all life vests except one were gone from the underseat container bags.

2.11.6.7 Target 399 - Left-Hand Side Triple Seat with Tray Arms

It would appear that this section was from row 18, seats A, B and C, the first set of triple seats aft of

door 2L. The notable damage to this unit was as follows: front leg aisle side buckled and crushed in place; front leg window side buckled and crushed in place; forward edge tube to seat broken and bent downwards at joint with fore and aft tube between window and centre seats; and fore and aft tube between centre and aisle seat broken at start of T-connection to rear edge of seat tube. The damage suggests that the failures resulted from vertical loading. All the life-jackets were in place.

2.11.6.8 Target 399 - Fuselage Side and 2R Entry Door

The fuselage segment was located between BS 780 and 940. This piece was badly damaged and buckled inwards along a line through the lower door hinge. There were 12 holes or damaged areas on the skin generally with petals bending outwards. The curl on a flap around a hole had one full turn. This curl was in the outward direction. Cracks were also noticed around some of the holes. Part of the metal was missing in some of the holes. The edges of some of the petals showed reverse slant fracture. In one of the holes, spikes were noticed at the edge of a petal.

When this target was recovered from the sea, along with it came a few hundred tiny fragments and medium-sized pieces. One of the medium-sized pieces recovered with this target was a floor stantion about 35 inches long. It was confirmed that this stantion belonged to the right side of the forward cargo hold. The inner face of the stantion had a fracture with a curl at the lower end, the curl being in the outboard direction and up into the centre of the stantion.

Scientists from the Bhabha Atomic Research Centre, the National Aeronautical Laboratory and the Explosives Research and Development Laboratory in India conducted a metallurgical examination of certain items of wreckage. Their report on target 399 concluded that:

- the curling of the metal on the floor channel was indicative of a shock wave effect;

- the large number of tiny fragments from the disintegration of nonbrittle aluminum was a characteristic indication of explosive forces; and

- the indications of punctures, outward petalling around holes, curling of metal lips, reverse slant fracture, formation of spikes at fracture edges and certain microstructural changes all were indicative of an explosion.

2.11.6.9 Target 193 - Fuselage Side and 2L Entry Door

The fuselage segment was located between BS 720 and 840. The door and fuselage skin were buckled outwards, approximately in line with the buckling on the fuselage and 2R entry door directly opposite.

2.11.6.10 Target 362/396 - Lower Skin Panel - Forward Cargo Area

This section of skin panel was located between BS 720 and 860 and is just below target 399. The skin was badly crumpled and torn and had several punctures. It was pulled free from a large mass of debris which included some mangled cargo floor beams and roller trays. Some of the punctures had a feathered or spiked profile, with spikes angled at approximately 45 degrees to the edge. Other puncture holes gave clear indication of being formed by underlying stiffeners at impact. Two of these holes contained pieces of web stiffener. Most of the punctures were the result of penetrations from inside.

In the preliminary report of Mr. V.J. Clancy, representing Boeing, the following observations regarding target 362/396 were made:

- There were about 20 holes in the lower skin panel clearly resulting from penetration from inside.

- In addition to the fact that perforation was from inside, there were certain features which suggested that they were made by high velocity fragments such as those produced by an explosion. Mr. Clancy's report describes these features as follows:

- the presence of toothed or spiked edges at some parts of the metal which has petalled out from the perforations;

  (Tardif and Sterling, Canadian Aeronautics and Space Journal, 1969, 15, 1, 19-27, obtained spiked fractures in fragments from sheet alloy subjected closely to an explosion. They stated that they had not obtained this effect in fractures otherwise produced.)

- the presence of marked curling (in some cases of more than 360 degrees) of some of the petals;

  (Tardif and Sterling stated that such curling was a feature of explosively produced fragments.)

- the virtual absence of scratches or score marks on the petals such as might be expected if something were slowly forced through the metal;

- the virtual absence of other impact marks on the inside surface such as might have been produced by a massive impact with a substantial object, thereby suggesting that the production of at least many of the perforations were separate independent events; and

- the presence of one perforation (identified as number 14) resembling a "bullet hole" that was clearly punched out - a type of hole usually associated with a high velocity missile.

- There was evidence that the forward part of the skin panel had been folded back inward along the line of station 760 and then bent back again along a line slightly forward of this station.

- Such folding, perhaps violently produced on impact with the water, could have brought broken metal of stringers or stiffeners into forceful contact with the internal surfaces, thus producing perforations outwards. The overlap of such folding would conceivably have covered the area up to station 800 and thus included most of the perforations.

- One hole (identified as number 13) was almost certainly caused by a slipping wire rope used as a sling.

- Part of the inner surface, aft of station 780 was superficially blackened as if by soot from a fire. Swabs were taken of this area for further examination for evidence of fire or explosives.

- A large number (several hundred) of small fragments were recovered. These varied in size from an inch or less to a few inches. They included fragments broken out of sheet metal, and these were reported to be from the same area as T362.

- The production of a large number of small fragments is generally regarded as an indication of an explosion.

- One piece, which was isolated, was about an inch square of sheet alloy with characteristic spikes on one edge similar to those described by Tardif and Sterling.

The following is an excerpt from the report by Mr. V.J. Clancy wherein he gives his opinion and conclusions regarding target 362.

"Opinion

The features discernible to a careful close visual examination point towards the possibility of an explosion but taken alone do not justify a firm conclusion.

Curling of petals and spiked or toothed fractures may be observed in other events than explosions despite the failure by Tardif and Sterling to obtain them in their limited number of attempts. It is probable that these features indicate a rapid rate of failure but not necessarily of a rapidity which could only be produced by an explosion.

A more detailed study, metallurgical and fractographic, is required.

The studies by Tardif and Sterling were done on fragments produced from aluminium alloy in contact with the explosive. Very little information is available on the behaviour of aluminium alloy some distance from the explosive and subjected to attack by secondary fragments. To determine this some trials will be necessary, to obtain reference samples for comparison.

The single "bullet hole," No. 14, strongly supports an explosion hypothesis but, being the sole example of its kind, is not, by itself determinative.

If the forward part of this item was forcefully and rapidly folded back to impact on the other part, it might explain the other features apparent to visual examination. It would require detailed laboratory examination and tests to eliminate this possibility.

The production of a large number of small fragments is generally regarded as a pointer towards an explosive cause but cannot be relied upon unless it is clear that they could not have been produced by some other means. It is known that the break-up of an aircraft at high speed may produce great fragmentation.

The single spiked fragment must be regarded as important but a single specimen is not, by itself, determinative."

Mr. Clancy concluded that:

"there is strong circumstantial evidence that an explosion occurred but neither individually nor collectively do the several pointers give the degree of confidence necessary for a firm and final conclusion, at this time."

With respect to target 362/396, in his report Mr. Clancy recommended:

"that firing trials be carried out projecting various size missiles at targets similar to the material of T362 to obtain reference samples for

laboratory comparison with the perforations in T362."

The Indian report, in addition to the observations made by Mr. Clancy, noted the following with respect to the metallurgical examination:

- The microstructure in the various areas examined on target 362/396 confirmed explosive loading in this part of the aircraft.

- The holes and other features observed in targets 362/396 and 399 must have been due to shock waves and penetration by fragments resulting from an explosion inside the forward cargo hold.

- The chemical nature of the explosive material was not identified. No part of an explosive device, its detonator or timing mechanism was recovered.

2.11.6.11 Examination of Wreckage in India with CASB Participation

The examination of the targets recovered did not reveal any pre-existing defect, premature cracking or pre-impact corrosion damage associated with any of the failures.

3.0 DISCUSSION

3.1 Initial Event

From the correlation of the recordings of the DFDR, CVR and Shannon ATC tape, the unusual sounds heard on the ATC tape started shortly after the flight recorders stopped recording. The conversations in the cockpit were normal, and there was no indication of an emergency situation prior to the loud noise heard on the CVR a fraction of a second before it stopped recording. The DFDR showed no abnormal variations in parameters recorded before it stopped functioning. The only unusual observation was the irregular signals recorded over the last 0.27 inches of the DFDR tape. Laboratory tests indicated the possibility that these signals resulted from the recorder being subjected to a sharp disturbance at the time it stopped recording. The other possibility for the irregular signals on the DFDR is that they were caused by a disturbance to the Flight Data Acquisition Unit in the main electronics bay. Since there was an almost simultaneous loss of the transponder signal, this indicates the possibility of an abrupt aircraft electrical failure. The medical evidence showed a general absence of signs indicating that seat-belts were fastened. From the video and photographic examination of the wreckage on the bottom, it was ascertained that the majority of seats located did not have the seat-belts fastened. The above evidence indicates that the initial occurrence was sudden and without warning. The abrupt cessation of the data recorder could be caused by airframe structural failure or the detonation of an explosive device as the initial event. The millisecond noise on a CVR as observed in this case is usually, as described in the available literature, the result of the shock wave from detonation of an explosive device. However, in this case, certain characteristics of the noise indicate the possibility that the noise was the result of an explosive decompression. There is some disagreement regarding the cause and location of the source of the noise heard on the CVR, that is, whether the noise resulted from an explosive device or an explosive decompression and whether the noise originated from the rear or closer to the front of the aircraft.

3.2 Passenger/Flight Deck Area

From the examination of the wreckage recovered and wreckage on the bottom, there is no indication that a fire or explosion emanated from the cabin or flight deck areas. The medical examination of the bodies also showed no fire or explosion type injuries. However, pieces of an overhead locker coming from above door 2R or 4R had been blackened by fire. There was blackened erosion damage to the bottoms of some seat cushions, showing damage possibly from an explosive device, and the upper deck storage cabinet had a large rounded dent in the bottom inboard edge which might have been caused by an explosive shock wave generated below the cabin floor and inboard from the cabinet. It should be noted that the pieces of the overhead locker were found on the Welsh shore some time after the accident, and it is not known if the pieces were subjected to a fire after the accident. Also, it is not known if the damage to the seat cushions and the upper deck storage cabinet could have been caused by other means. Nevertheless, the above evidence suggests that some areas of the passenger cabin may have been subjected to minor fire and explosive damage possibly emanating from below the cabin floor.

3.3 Aircraft Break-up Sequence

The medical evidence showed a proportion of the passengers with indications of hypoxia, decompression, flail injuries and loss of clothing. The incidence of hypoxia and decompression indicates that the aircraft experienced a decompression at a high altitude. The flail injuries and loss of clothing indicate a proportion of the passengers were ejected from the aircraft before water impact. The severity of injuries increased from Zones C to E and was significantly less in Zone C than in Zones D and E.

The wreckage of the forward portion of the aircraft up to and including the aircraft body wheel well area and the wings was lying about 0.8 miles north of the vertical and horizontal stabilizers. Hence, it is likely that the aft portion of the aircraft separated from the forward portion before striking the water. In addition, the wreckage found west of longitude 12°48'

consisted of suitcases and aft cargo compartment lower skin panels. There was also a wide scatter of sections 46 and 48 in an east-west direction, whereas the wreckage of the forward portion was mainly localized within a relatively small area.

The higher severity of injuries in the aft end of the passenger cabin appears to coincide with the break-up of the aft end, sections 46 and 48 of the aircraft. The fact that items from the aft cargo compartment were found further west than the tail section indicates that the aft cargo compartment ruptured first during the break-up sequence of the aft end. The forward portion of the aircraft was highly localized, which indicates that it struck the water in one large mass.

3.4 Aircraft Structural Integrity

As described earlier, the sudden nature of the occurrence indicates the possibility of a massive airframe structural failure or the detonation of an explosive device.

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. In addition, the right wing root interior area appears to have been scorched briefly by a heat source. The fan cowls of the number 4 engine show evidence of being struck by a portion of the turbine from number 3 engine.

The number 3 engine nacelle strut was separated from the rest of the engine components and was located about one nautical mile to the west indicating that there was some break-up of the number 3 engine before water impact.

The forward cargo door which had some fuselage and cargo floor attached was located on the sea bed. The door 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 and the fracture surfaces of the door appeared to be badly frayed. This damage was different from that seen on other wreckage pieces. A failure of this door in flight would explain the impact damage to the right wing areas. The door failing as an initial event would cause an explosive decompression leading to a downward force on the cabin floor as a result of the difference in pressure between the upper and lower portions of the aircraft. However, examination showed that the cabin floor panels separated from the support structure in an upward direction. Also, passenger seats viewed and recovered exhibited that they had been subjected to an upward force from below. They showed that the seats to the rear in sections 46 and 48 had their back legs buckled, and the seats toward the front had both front and back legs buckled. This indicates the vertical force was greater at the front than the rear of the aircraft. It is possible that this vertical force on the floor was caused by the force of the water during impact, but the rear of the aircraft broke up before impact and therefore any vertical loading on the floor in this area is unlikely to have occurred at impact. Twenty-three passengers also showed evidence of vertical impact injuries. These could have been caused from a force from below during flight or at water impact. Sixteen of these passengers had little or no clothing indicating that some may have been ejected before water impact. Therefore, there is some indication that the upward force on the floor may have occurred in flight and was more severe toward the front.

3.4.2 Aft Pressure Bulkhead

The localized impact mark found on the leading edge of the right horizontal root leading edge is indicative of an object striking the stabilizer in flight before water impact. This suggests that the loss of the tail plane was not the first event. The horizontal and vertical stabilizers were found separated and each was intact and in good condition. Items from the aft cargo compartment were found further to the west of the tail plane. The absence of the type of damage to the tail

plane as was found in the Japan Airlines (JAL) Boeing 747 accident where the aft pressure bulkhead failed and which took place shortly after this occurrence, and the rupture of the aft cargo compartment before the loss of the tail indicate that there was not an in-flight failure of the aft pressure bulkhead. In addition, examination of the recovered portions of the bulkhead shows evidence of overload failures from the rear to front only and no evidence of any pre-existing defect, premature cracking or pre-impact corrosion damage.

3.4.3 Target 7 - Lower Fuselage Skin Panel

Target 7 which extends from BS 1480 to 1860 shows a break at the joint at BS 1480. The forward keel joint splice plate is bent and the keel joint holes are distorted and elongated. Some of the fracture surface was heavily corroded. An in-flight failure in this area would cause a massive failure of the aircraft's structural integrity. Further examination showed the fractures to be overload, and there was no evidence of an intergranular type fracture to suggest a stress corrosion cracking mode of failure. The corrosion was concluded to be post-impact and, therefore, there is no evidence to suggest an in-flight failure in this area as the initial event.

3.4.4 Structural Failure

The examination of the floating and recovered wreckage and the analysis of the photos and videos of the wreckage on the bottom failed to indicate any evidence of a failure of the primary or secondary structure as a result of a pre-existing defect. The initial event has been established as sudden and without warning. The abrupt cessation of the flight recorders indicates the possibility of a massive and sudden failure of primary structure; however, there is evidence to suggest that there were ruptures in the forward and aft cargo compartments prior to any failure of the primary structure in flight. Therefore, available evidence tends to rule out a massive structural failure as the initial event.

3.4.5 Explosive Device

A violent explosion occurring within an aircraft in flight usually leads to a complicated break-up mode and sequence of failure. Fractures of metal caused by an explosion are normally different in character to those caused by overstressing or crash impact forces. Shattering of metal into very small and numerous fragments and minute deep penetration of a metal surface are not usually found in aircraft accident wreckage. The size and characteristics of these particles often accompanied by rolled edges, surface spalling, pitting or evidence of heat are indicative of an explosion.

Of the floating wreckage, there is little to indicate the possibility of an explosion:

- the lining in one suitcase was severely tattered;
- although the wooden spares box was burned, this could have happened after the occurrence;
- although pieces of an overhead locker were damaged by fire, it is not known if the burning happened at the time of the occurrence;
- although the pieces of U-section alloy clearly indicated evidence of an explosion, it is quite possible that these pieces were not associated with the aircraft;
- the bottoms of some seat cushions show indications of a possible explosion;
- the inside of the right wing root fillet appears to have been scorched; and
- the deformation of the floor of the upper deck storage cabinet might have been caused by an explosive shock wave generated below the cabin floor and inboard from the cabinet.

It is not known if the suitcase came from the aft or forward cargo compartment, and the location of the seats from which the cushions came is also unknown.

The scorching of the right wing root fillet and the damage to the upper deck cabinet suggest, if there was an explosion, it emanated from the forward cargo compartment.

From the examination of the recovered wreckage, the following deductions can be made:

- Target 47, which is a portion of the aft cargo compartment roller floor, shows no indications characteristic of an explosion emanating from the aft cargo compartment.

- Target 362/396, which is a lower skin panel from the forward cargo compartment is badly crumpled and torn and has about 20 punctures resulting from penetration from inside. It appears that some folding occurred on water impact which brought stringers or stiffeners from the aircraft structure into forceful contact with the internal surface of the panel producing most of the penetrations. However, there are certain punctures which indicate no evidence of impact marks on the inside surface and show evidence of being produced by high velocity fragments. Part of the inner surface of the skin panel appeared to have been blackened by soot from a fire.

- Target 399, consisting of a piece of the skin and stringers on the right side in the area of the forward cargo compartment contained holes and several hundred metal fragments. The damage to the floor stantion and the presence of the fragments are consistent with an explosion.

The examination of the recovered wreckage contains no evidence of an explosion except for targets 362/396 and 399 which contain some evidence that an explosion emanated from the forward cargo compartment.

An explosion in the forward cargo compartment would explain the loss of the DFDR, CVR and transponder signal as the electronics bay is immediately ahead of the cargo compartment.

3.5 Security Aspects

There is a considerable amount of circumstantial and other evidence that an explosive device caused the occurrence. Therefore, it is reasonable to examine the security measures in place on 22 June 1985. The evidence indicates that if there was an explosion, it most likely occurred in the forward cargo hold, not the passenger and flight deck areas or exterior to the fuselage. Although an explosive device could have been placed in a cargo hold in a number of ways, the available evidence points to the events involving the checked baggage of M. and L. Singh in Vancouver. The investigation determined that a suitcase was interlined unaccompanied from Vancouver via CP Air Flight 060 to Toronto. In Toronto, there is nothing to suggest that the suitcase was not transferred to Terminal 2 and placed on board Air India Flight 181/182 in accordance with normal practice. The aircraft departed Toronto for Mirabel and London with the suitcase unaccompanied. Similarly, a suitcase was interlined unaccompanied on CP Air Flight 003 from Vancouver to Tokyo to be placed on Air India Flight 301 to Bangkok. The explosion of a bag from CP 003 at Narita Airport, Tokyo, took place 55 minutes before the AI 182 accident. Therefore, the nature of the link between the two occurrences raises the possibility that the suitcase which was unaccompanied on AI 182 contained an explosive device.

3.5.1 Canadian Security Situation

Canadian security arrangements in place prior to 23 June 1985 met or exceeded the international requirements for civil air transportation. However, before this date, the emphasis was on preventing the boarding of weapons including explosive devices in hand luggage. Hence, the screening of checked baggage was only undertaken in conditions of a heightened threat as was the case with respect to Air India flights.

In Canada, the Department of Transport (Transport Canada) is responsible for establishing overall security standards for airports and airlines, and for the provision of certain security equipment and facilities at airports. By regulation, air carriers are responsible for applying security standards for

passengers, for baggage and cargo and for ensuring security within individual aircraft. The RCMP provides airport physical security and responds to criminal incidents.

Air carriers contract for or otherwise provide the personnel who operate the security check-points through which passengers and their carry-on baggage enter the secure area of the airport terminal. These personnel also operate security equipment for the screening of cargo, passengers and checked baggage. Usually, air carriers use the service of private security firms. Transport Canada has established certain standards required for licensed security guards, such as the successful completion of the Transport Canada passenger inspection training program and annual refresher training. As stated earlier, a significant number of the security guards did not meet the criteria with respect to the completion of the training program and refresher training. In addition, the criteria do not require training for the screening of cargo and checked baggage.

ICAO Annex 17 recommends that contracting States establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage or cargo intended to be carried on board aircraft. For all Canadian airlines, Canadian regulations before 23 June 1985 required a system of identification that prevented baggage, goods and cargo from being placed on board an aircraft if it was not authorized to be placed on board by the airline operator. However, if someone were to purchase a ticket, check in baggage and not board the aircraft, the baggage would in all likelihood have been authorized by the airline to be placed on board the aircraft. Therefore, it was possible to interline baggage unaccompanied and this explains how a suitcase was interlined to AI 181/182 from CP 060. It is not the normal practice of airlines to interline baggage if there is not a confirmed reservation to the destination. In this case, the ticket agent allowed the suitcase to proceed; however, if there had been a confirmed reservation, the suitcase would have been interlined unaccompanied without question.

3.5.2 Air India Security

Air India, as required by Canadian regulation, had a security program. Because of the threat level assessed against the airline, Air India had more extensive security measures than almost any other Canadian or international airline. These measures were generally in accordance with the recommended procedures of the ICAO Security Manual for special risk flights. Air India had also requested and received extra security from Transport Canada and the RCMP for the month of June 1985. For Air India Flight 181/182, Air India provided a security officer from its New York office to oversee the security arrangements at Toronto and Mirabel. The security program at each airport was under the overall supervision of the respective Air India station managers. In Toronto, it was not clear who, if anyone, was undertaking this function.

It is not known if the suitcase interlined from CP 060 was screened before or after the X-ray machine broke down in Toronto. Although baggage not examined by X-ray was screened by a PD-4 sniffer, there are indications that the sniffer could have been ineffective in detecting explosives, especially plastics. Rather than using the sniffer, it would have been more effective to open all bags and physically inspect them. Even though a number of security personnel were not adequately trained in the screening of passengers and baggage, it is not known whether more training would have prevented an explosive device from being placed on board.

Although airline procedures required baggage to be accompanied, the agents checking in passengers in Toronto used a passenger security numbering system but did not number checked-in baggage, and baggage was not correlated with passengers. Therefore, the interlined unaccompanied suitcase from CP 060 was not detected. At Mirabel, checked-in passengers and baggage were numbered so that the number of passengers checking in baggage could be correlated with the number of passengers boarding the aircraft. Had a passenger-baggage correlation been carried out in Toronto, the suitcase from CP 060 would have been detected. The

airline procedures would have prevented the placement of the suitcase on the aircraft.

Once loaded on the aircraft, the suitcase would have been placed in container 11L and 12L (see Appendix B) if in the forward cargo compartment, in container 44L or 44R if in the aft cargo compartment, or in position 52 if in the bulk cargo compartment. It could not be determined in which cargo compartment the suitcase was loaded.

Therefore, although the procedures were in place to prevent an explosive device from being placed on board the aircraft in checked-in baggage, there was a breakdown in the X-ray machine used to screen baggage, and there are indications that the PD-4 sniffer was inadequate. Also, the security numbering system used in Toronto was ineffective in preventing unaccompanied interlined baggage from being placed on board the aircraft.

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.

4.2 Other Findings

Even though they may not be causal or related to the accident, the following additional conclusions can be drawn from the investigation with respect to certain security arrangements and their application pertaining to this flight:

1. In compliance with the International Civil Aviation Organization Annex 17 to the Convention on International Civil Aviation, the Department of Transport of Canada has made regulations requiring foreign aircraft operators who land in Canada to establish, maintain, and carry out certain security measures at airports.

2. In accordance with these regulations, Air India submitted a security program to the Minister of Transport which included security measures with respect to aircraft, cargo, baggage, and passengers.

3. On 22 June 1985, an unaccompanied suitcase was interlined from Vancouver to Toronto on CAP Flight 060 for transfer in Toronto to Air India Flight 181/182.

4. The baggage loaded in Toronto was screened through an X-ray machine process but, during the course of this procedure, the X-ray machine broke down.

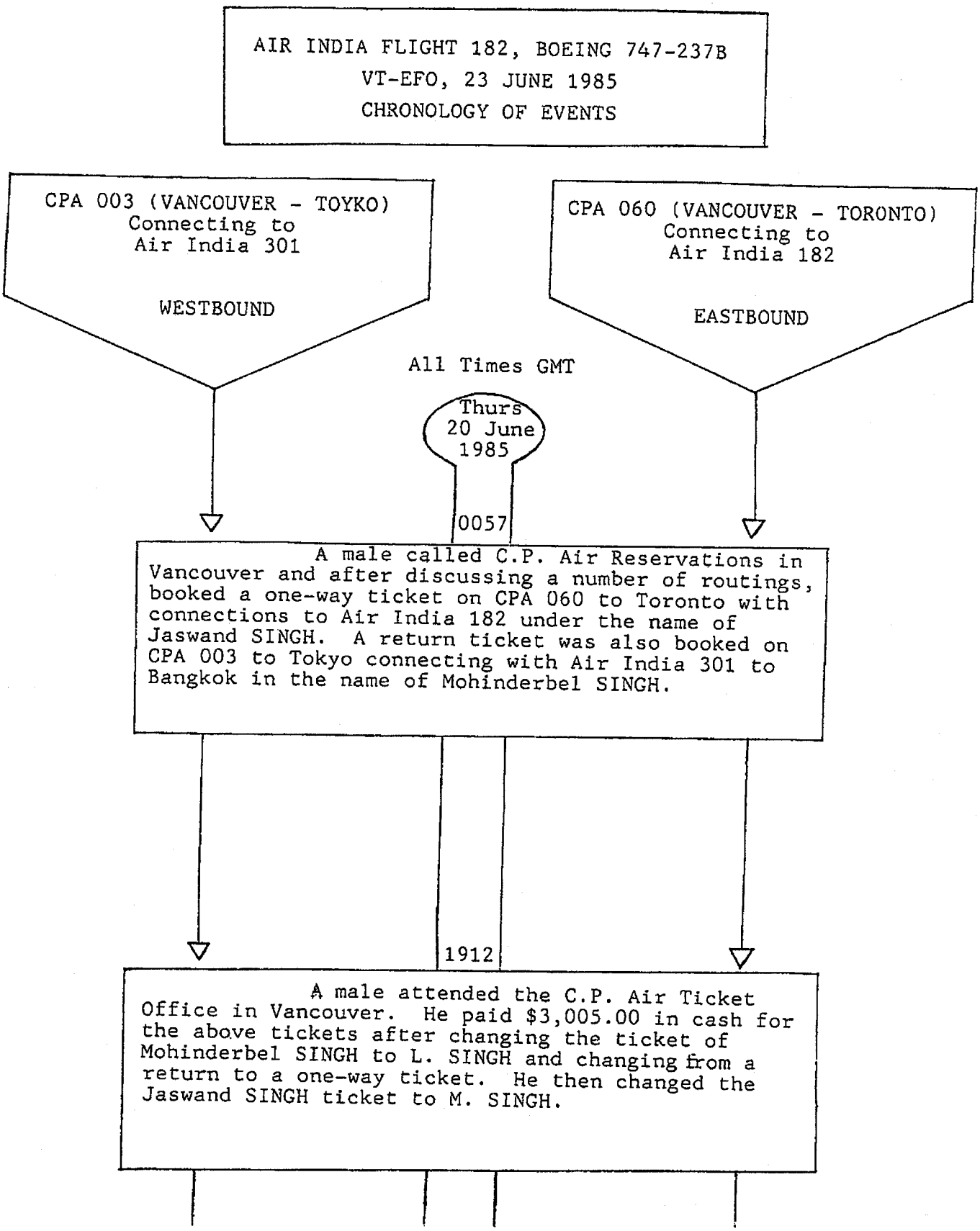
5. After the X-ray machine breakdown, an explosives detector was used to screen the baggage; the baggage was not opened and physically examined.

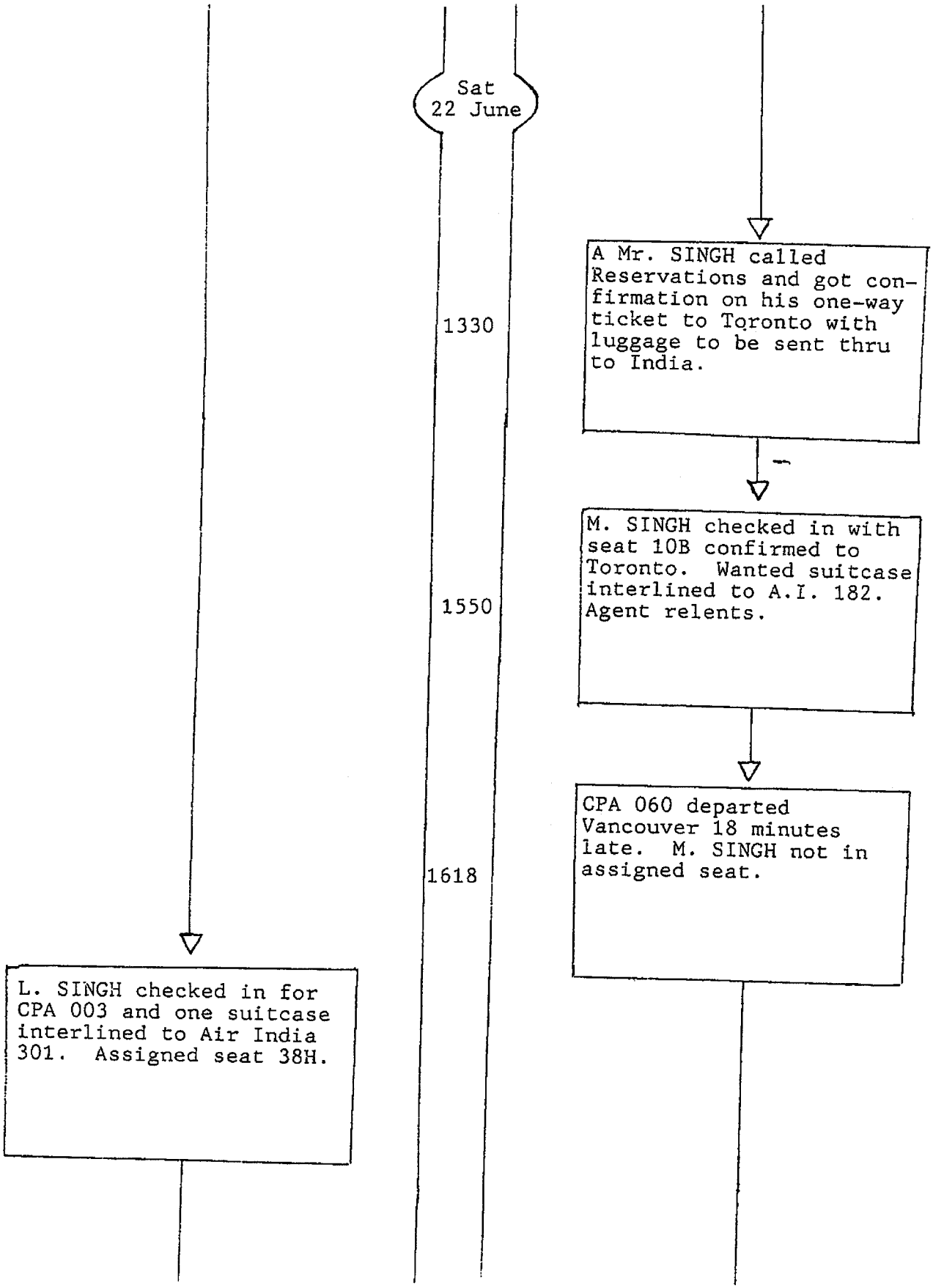
6. The effectiveness of the explosives detector is in doubt.

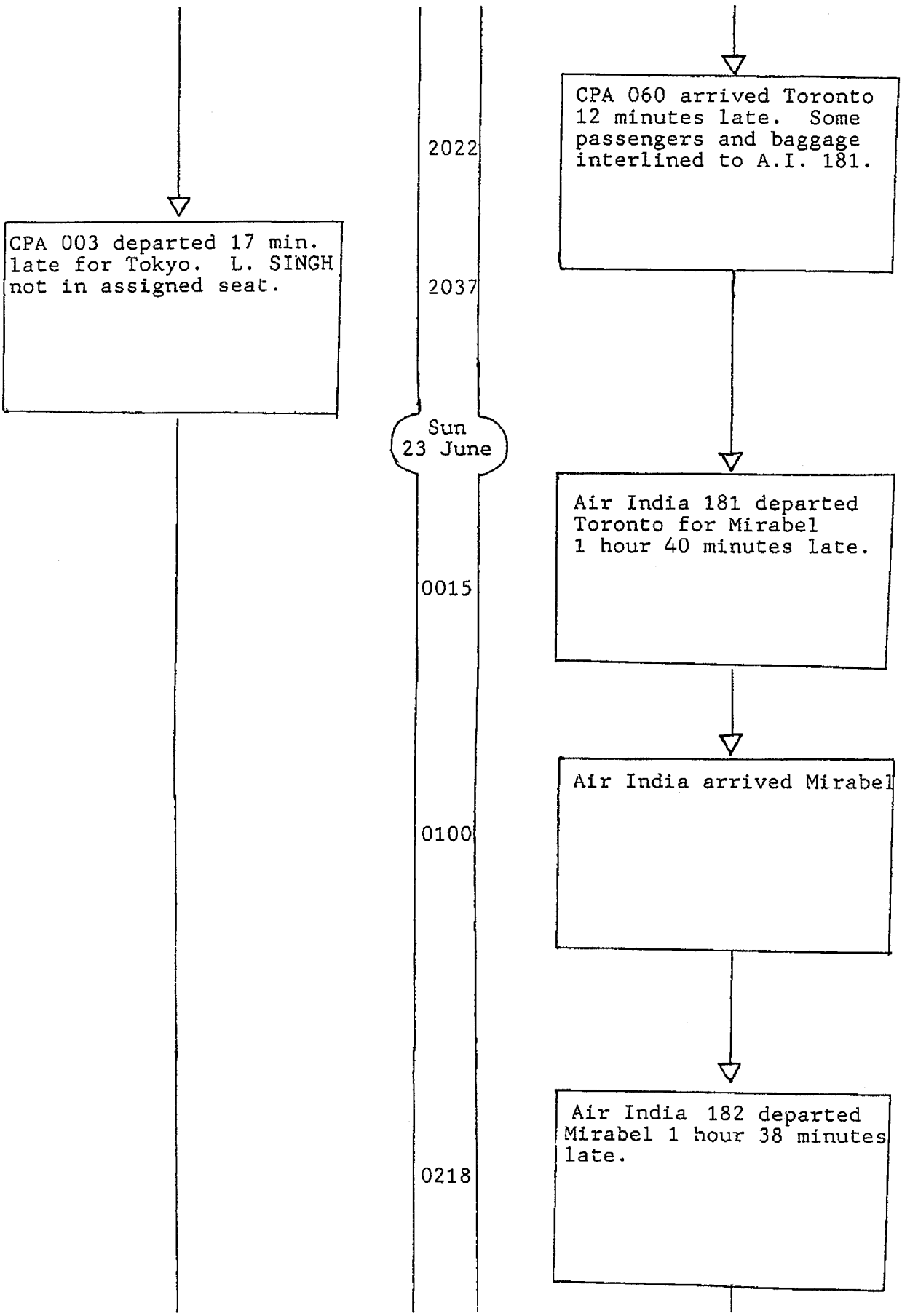
7. It is not known whether the unaccompanied suitcase interlined from Vancouver was screened before or after the X-ray machine broke down.

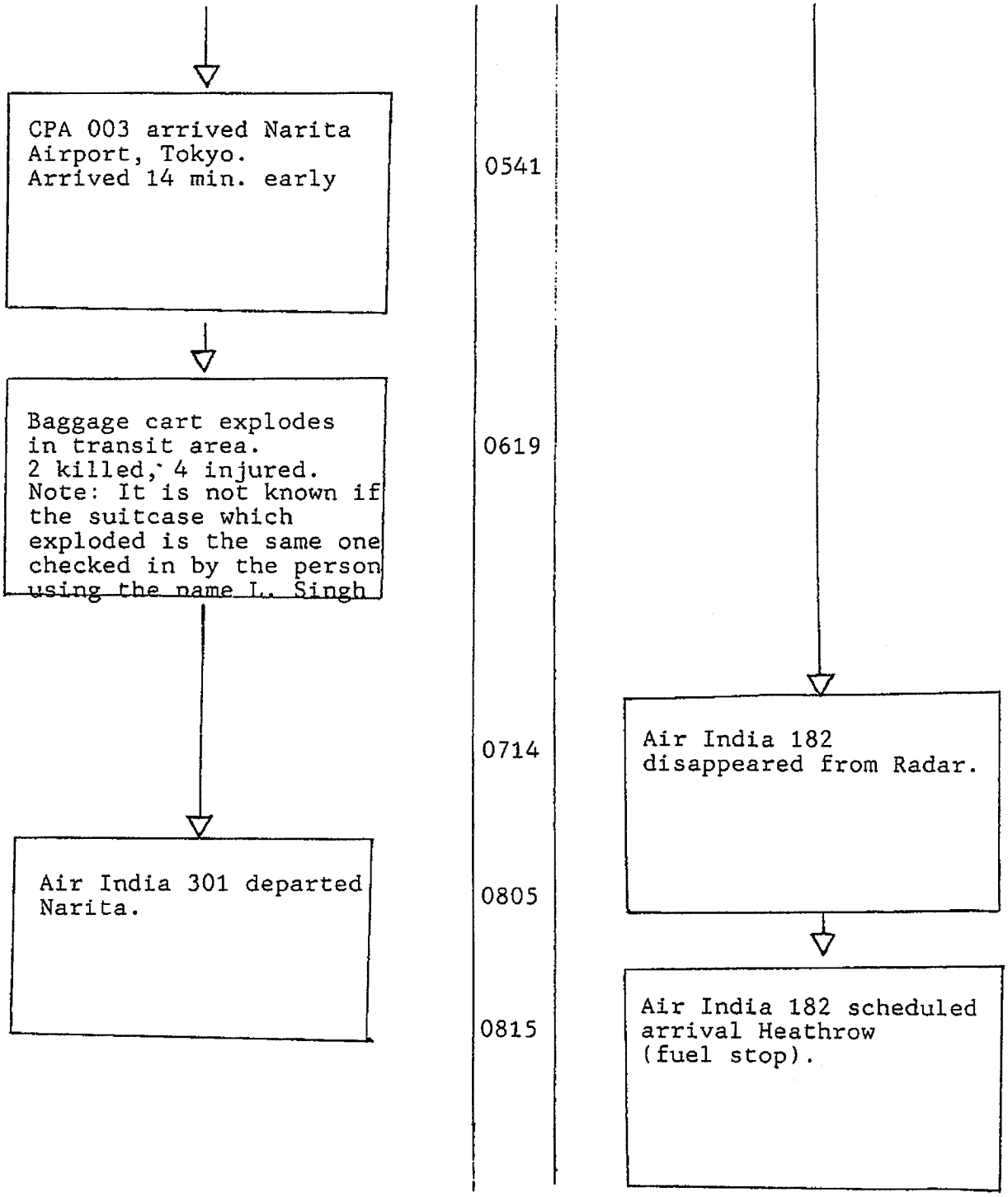
8. The security numbering system used in Toronto did not prevent unaccompanied interlined baggage from being placed on board the aircraft.

9. The normal procedures for interlining baggage in Toronto indicate that the unaccompanied suitcase was loaded on Air India Flight 181/182.


AIR INDIA FLIGHT 182, BOEING 747-237B
VT-EFO, 23 JUNE 1985
CHRONOLOGY OF EVENTS
CPA 003 (VANCOUVER - TOYKO)
Connecting to
Air India 301
WESTBOUND
CPA 060 (VANCOUVER - TORONTO)
Connecting to
Air India 182
EASTBOUND
All Times GMT
Thurs
20 June
1985
0057
A male called C.P. Air Reservations in Vancouver and after discussing a number of routings, booked a one-way ticket on CPA 060 to Toronto with connections to Air India 182 under the name of Jaswand SINGH. A return ticket was also booked on CPA 003 to Tokyo connecting with Air India 301 to Bangkok in the name of Mohinderbel SINGH.
1912
A male attended the C.P. Air Ticket Office in Vancouver. He paid $3,005.00 in cash for the above tickets after changing the ticket of Mohinderbel SINGH to L. SINGH and changing from a return to a one-way ticket. He then changed the Jaswand SINGH ticket to M. SINGH.


Sat
22 June
1330
1550
1618
A Mr. SINGH called Reservations and got confirmation on his one-way ticket to Toronto with luggage to be sent thru to India.
M. SINGH checked in with seat 10B confirmed to Toronto. Wanted suitcase interlined to A.I. 182. Agent relents.
CPA 060 departed Vancouver 18 minutes late. M. SINGH not in assigned seat.
L. SINGH checked in for CPA 003 and one suitcase interlined to Air India 301. Assigned seat 38H.


CPA 003 departed 17 min. late for Tokyo. L. SINGH not in assigned seat.
2022
CPA 060 arrived Toronto 12 minutes late. Some passengers and baggage interlined to A.I. 181.
2037
Sun 23 June
Air India 181 departed Toronto for Mirabel 1 hour 40 minutes late.
0015
Air India arrived Mirabel
0100
Air India 182 departed Mirabel 1 hour 38 minutes late.
0218


CPA 003 arrived Narita Airport, Tokyo. Arrived 14 min. early
0541
Baggage cart explodes in transit area. 2 killed, 4 injured. Note: It is not known if the suitcase which exploded is the same one checked in by the person using the name L. Singh
0619
Air India 182 disappeared from Radar.
0714
Air India 301 departed Narita.
0805
Air India 182 scheduled arrival Heathrow (fuel stop).
0815

AIR INDIA FLIGHT 182, BOEING 747-237B

VT-EFO, 23 JUNE 1985

LOADING - FORWARD CARGO COMPARTMENT

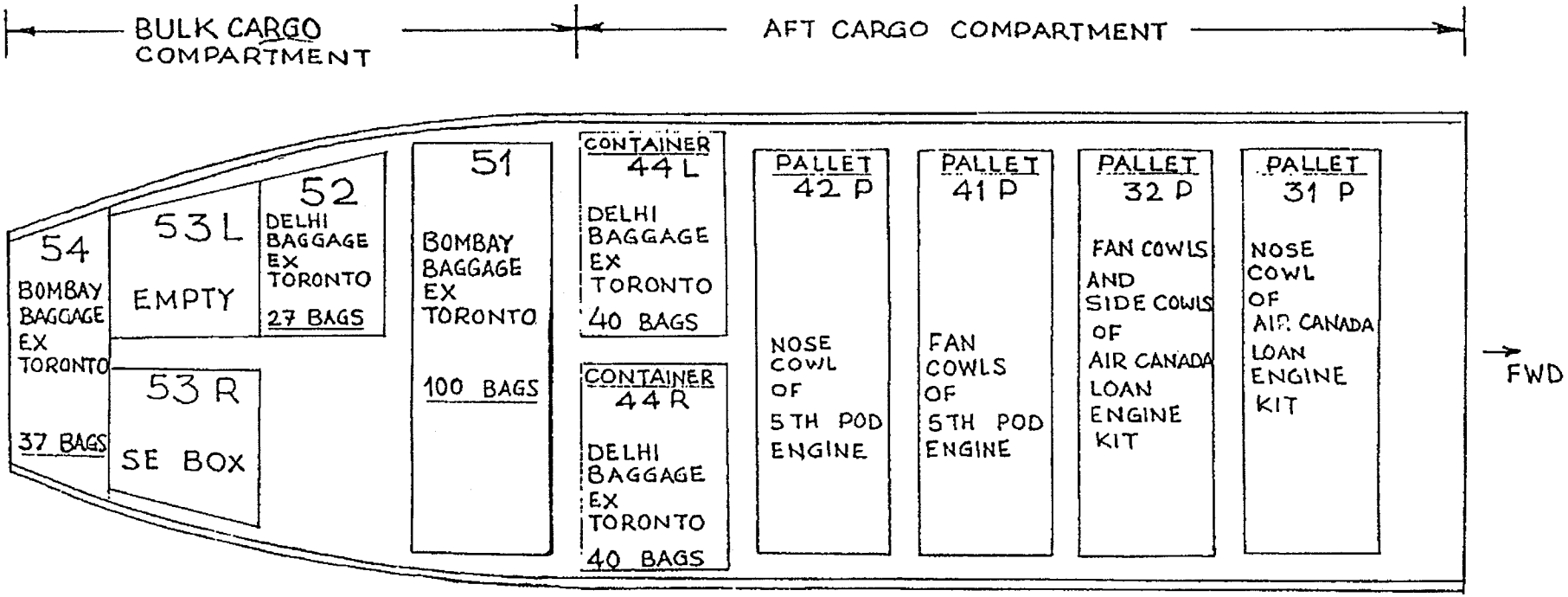
CONTAINER 24L FAN BLADES IN 12 WOODEN BOXES - 7@ STARTER, STARTER SOV, 30 BLEED LOCKOUT KIT ETC.	CONTAINER 23L BOMBAY BAGGAGE Ex. TORONTO 14 BAGS	CONTAINER 22L EMPTY	CONTAINER 21L EMPTY	CONTAINER 14L EMPTY	CONTAINER 13L FIRST CLASS AND LONDON BAGGAGE 35 BAGS	CONTAINER 12L DELHI BAGGAGE Ex. TORONTO 40 BAGS	CONTAINER 11L DELHI BAGGAGE Ex. TORONTO 35 BAGS
CONTAINER 24R BOMBAY BAGGAGE Ex. MONTREAL 43 BAGS	CONTAINER 23R BOMBAY BAGGAGE Ex. MONTREAL 38 BAGS	CONTAINER 22R DELHI BAGGAGE Ex. MONTREAL 42 BAGS	CONTAINER 21R DELHI BAGGAGE Ex. MONTREAL 38 BAGS	CONTAINER 14R VALUABLES (VAL) 10K6 *	CONTAINER 13R CREW BAGGAGE TORONTO-LONDON 34 BAGS	CONTAINER 12R DELHI BAGGAGE Ex. MONTREAL 19 BAGS	CONTAINER 11R EMPTY

FWD →

* TWO DIPLOMATIC BAGS (VANCOUVER - DELHI) LOADED AT TORONTO,
AIR INDIA DOCUMENTS IN AN ENVELOPE (TORONTO - DELHI),
ONE DIPLOMATIC MAIL BAG (OTTAWA - DELHI) LOADED AT MONTREAL,
ONE MEDICINE PACKET (MONTREAL - DELHI) AND
AIR INDIA MAIL BAG

Appendix B

LOADING - AFT AND BULK CARGO COMPARTMENTS

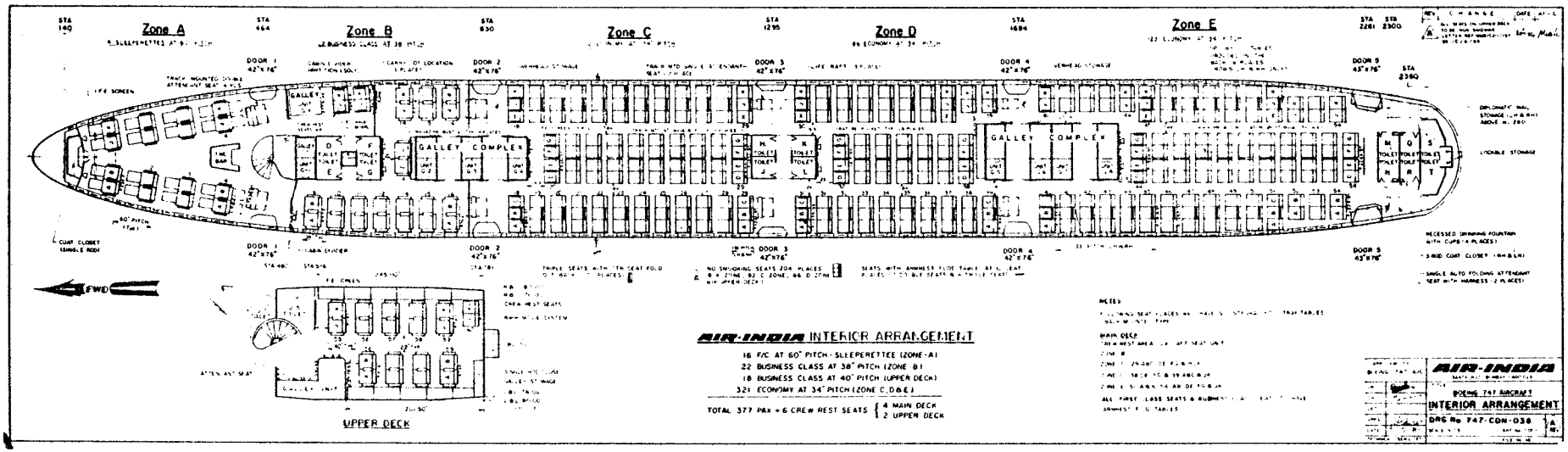


Appendix B

AIR INDIA 182, BOEING 747-237B

VT-EFO, 23 JUNE 1985

ZONE SEATING ARRANGEMENT

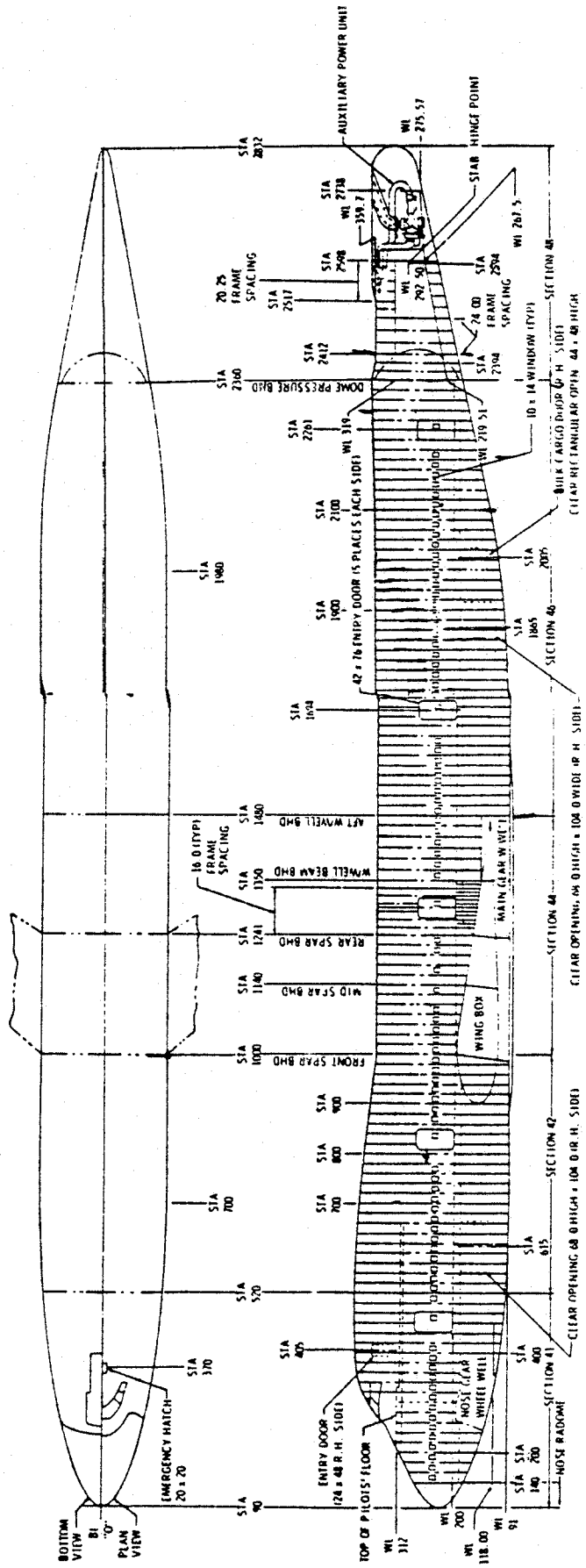


Appendix C

AIR INDIA FLIGHT 182, BOEING 747-237B

VT-EFO, 23 JUNE 1985

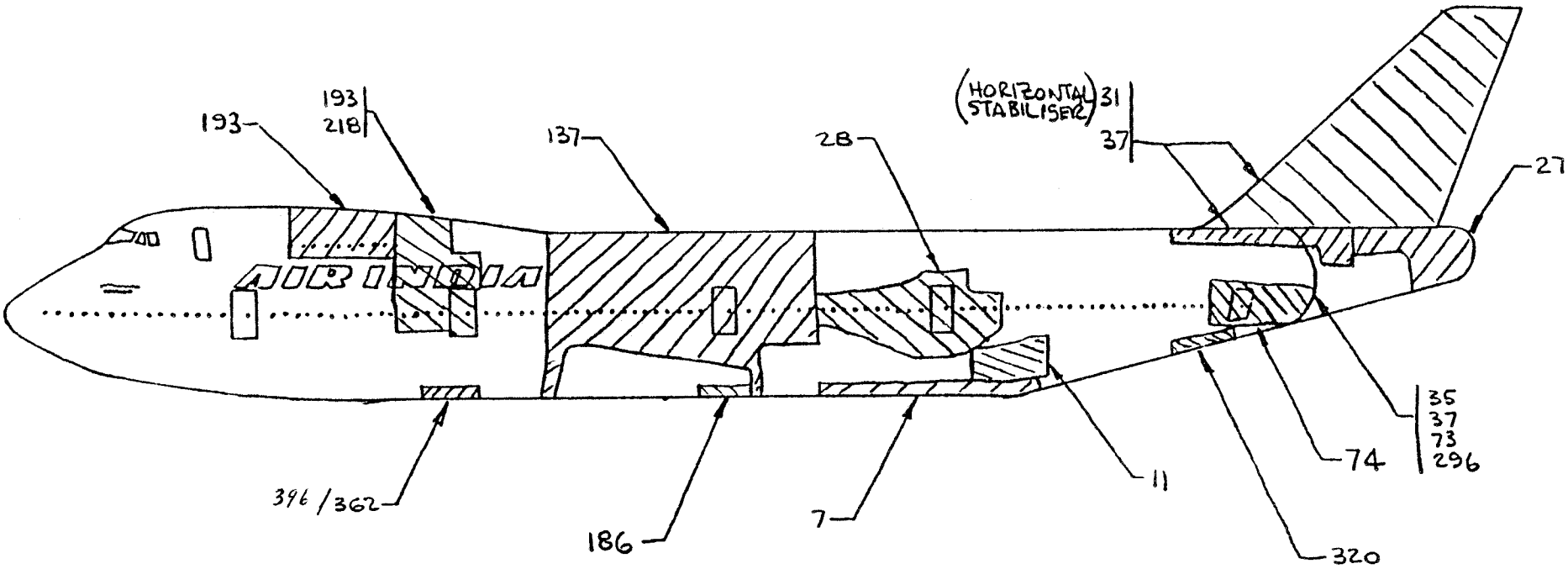
AIRCRAFT SECTIONS AND BODY STATIONS



AIR INDIA FLIGHT 182, BOEING 747-237B

VT-EFO, 23 JUNE 1985

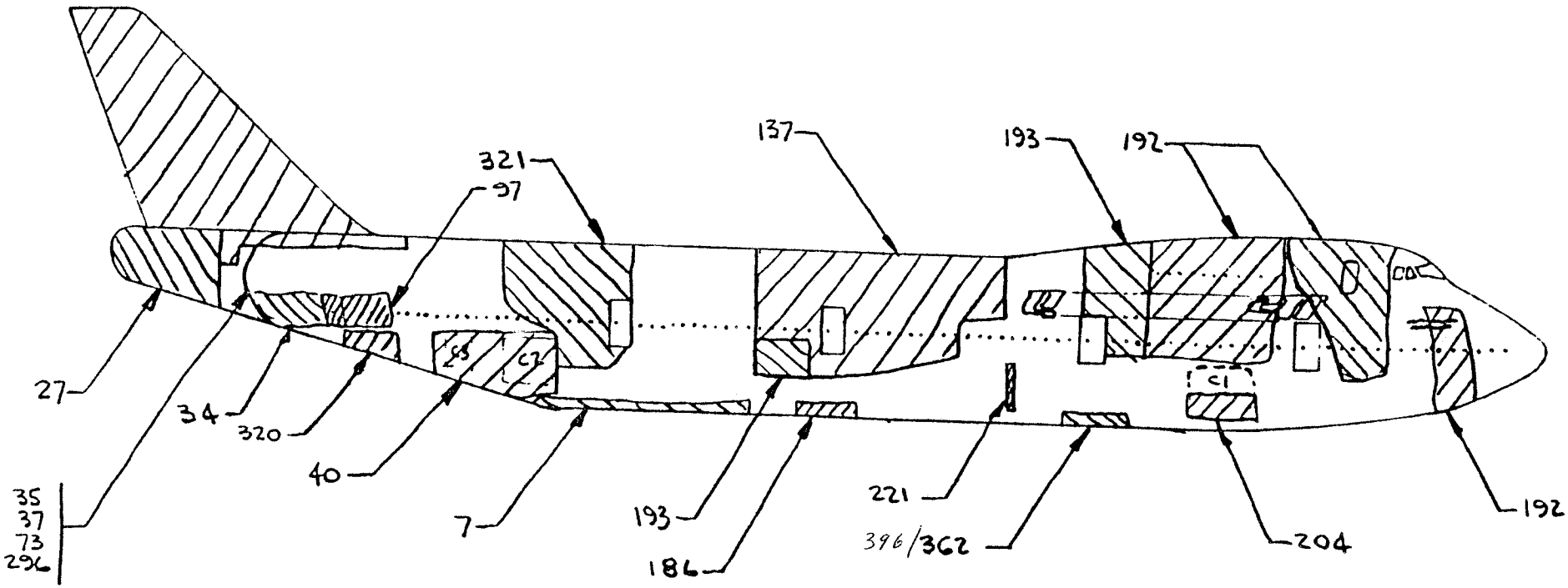
TARGET LOCATION



LEFT SIDE

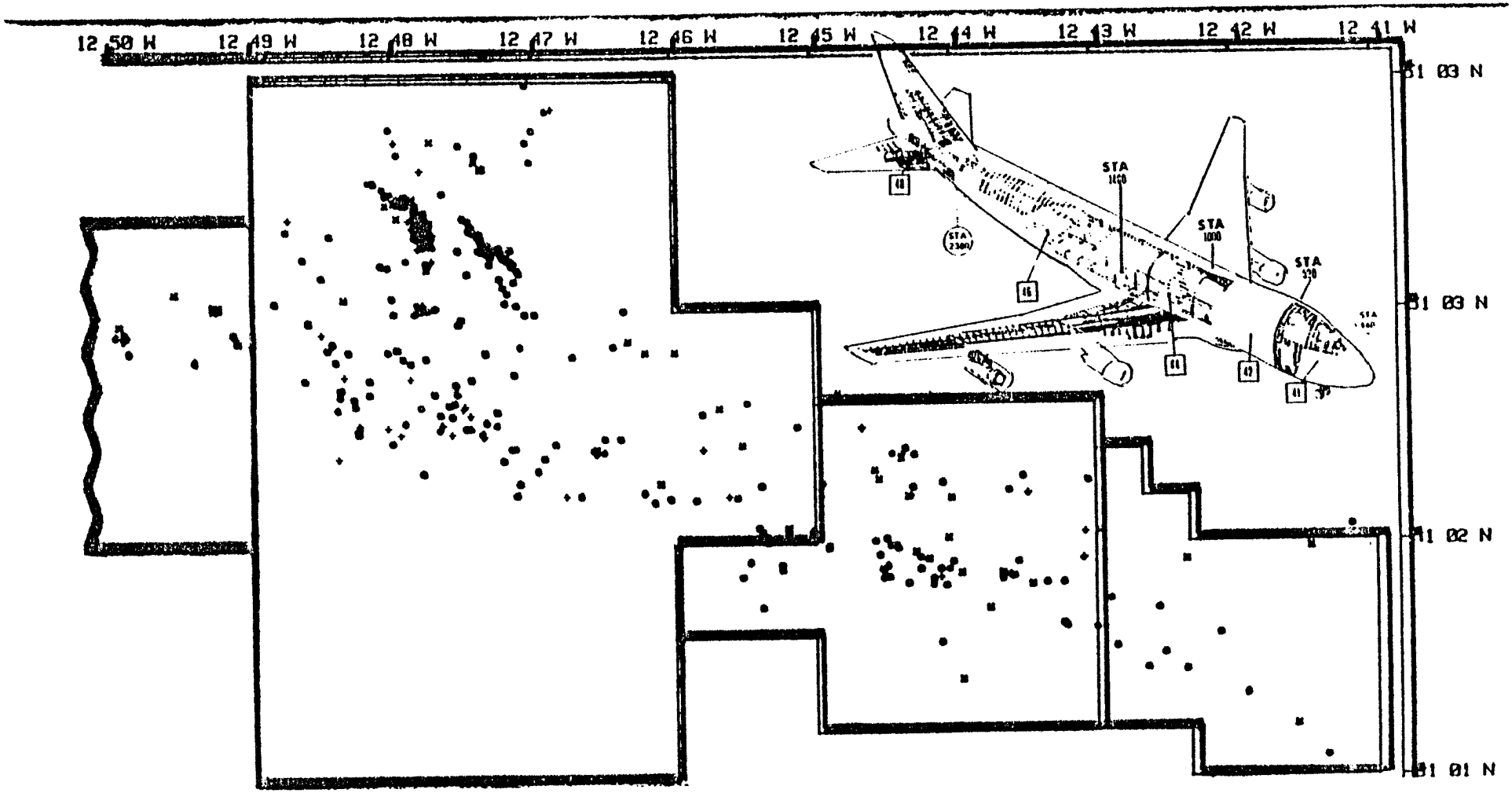
Appendix E

TARGET LOCATION



RIGHT SIDE

AIR INDIA FLIGHT 182 BOEING 747-237B
VT-EFO
23 JUNE 1985



+- Wing Components
O-Engine/Parts/Struts
x-Aircraft Cargo Structure/
Containers/Cargo

O-Aircraft Structure/Location not identified
O-Interior Structure/Cells/Seats/Etc

Appendix F