

TABLE OF CONTENTS

SECTION HEADING, PAGE

1.0

INTRODUCTION

2.0 ICAO BACKGROUND I- 3.0 CASB/TSB BACKGROUND -I- 4.0 C AVIATION INVESTIGATION (1985 TO 1986) -2- 5.0 ANALYSIS WORK FOR RCMP (1988 TO PRESENT) - -2- 6.0 STRUCTURAL BREAKUP ANALYSIS -5- 6.10 Breakup Analysis of the For-ward Half of the Aircraft Fuselage (Sections 41, 42, 44) -7- 6.13 Breakup Analysis of the Rear Half of the Aircraft Fuselage (Sections 46 and 48) -8- 6.16 Breakup Analysis of the A-ft Cargo and Bulk Cargo Compartments -9- 6.17 Target "7 -9- 6.22 Target "81, -1 I- 6.24 Target "47 -1 I- 6.26 Target "307 -11- 6.28 Deformation Patterns -12- 6. -'I I Aircraft Pressurization -12- 6.3') Structural Breakup Analysis Summary -13- 7.0 TRAJECTORY/WRECKAGE PATTERN.ANALYSIS -1,j- 7. 1 1 Trajectory/Wreckage Pattern Summary -17- 8.0 SYNOPSIS -17-

AIRCRAFT OCCURRENCE INVESTIGATION REPORT

Air India Flight 182, "Kanishka"
Boeing 747-237B, VT-EFO

North Atlantic Ocean

110 Miles West of Cork, Ireland
23 June 1985

by: John H. Garstang

16 March 2001

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LIST OF APPENDICES

Appendix "A": Boeing 747-200 Fuselage Diagrams showing Section Numbers and Station (STA) Numbers.

Appendix "B": Boeing 747-200 3D CAD Fuselage Model with Exterior Paint Scheme showing Isometric Views of the following combinations:

- *Appendix "B 1 ": Skin Targets, Passenger Floor Plan, Cargo Areas.
- *Appendix "B2": Skin Targets, Cargo Areas.
- *Appendix "B3": Skin Targets.
- *Appendix "B4": Passenger Floor Plan, Cargo Areas.

- *Appendix "B5": Cargo Areas.
- *Appendix "B5A": Forward Cargo.
- *Appendix "B5B": Aft Cargo.

Appendix "C": Boeing 747-200 3D CAD Fuselage Model showing Top, Bottom, Left and Right Side

Views of Skin Targets.

Appendix "D": Side Views of the Aft Fuselage showing Skin Targets, Pallets, Baggage Containers and Bulk Cargo Regions:

0 Appendix "D1": Left Side View. 0 Appendix "D2": Right Side View.

Appendix "E": Top View of the Aft and Bulk Cargo Compartment Floors showing the following combinations:

Appendix "E1": Skin Targets, Pallets, Baggage Containers and Bulk Cargo Regions. Appendix "E2": Floor Targets, Pallets, Baggage Containers and Bulk Cargo Regions. Appendix "F": Sample of Positional Data for Positively Identified Targets. Appendix "G": Plot of All Targets on a Universal Transverse Mercator Grid. Appendix "H": Plot of Targets: Northern Wreckage Trail (Sections- 41, 42, 44) and Southern Wreckage Trail (Sections: 46, 48) on a Universal Transverse Mercator Grid. Appendix "I": Plot of Targets: Northern Wreckage Trail (Sections- 41, 42, 44), Southern Wreckage Trail (Sections- 46, 48), Engine Parts (Sections: 7.11, 7.12, 7.13, 7.31), Wing Parts (Sections- 12, 14, 15, 16, 17, 18) and the first item found (Target "IA"- Suitcase) on a Universal Transverse Mercator Grid.

1.0 INTRODUCTION

1.1 This report summarizes my observations and conclusions pertaining to the investigation into the Air India Flight 182 occurrence. Some historical background information will be presented first in order to explain the role of some agencies, the timing of some events, and my involvement and/or interaction. Short briefs will then be given on the technical aspects of my work for the Royal Canadian Mounted Police (RCMP) Air India Task Force (AITF). This work was concentrated in two main areas:

Structural Break-up Analysis and, Trajectory/Wreckage Pattern Analysis

2.0 ICAO BACKGROUND

2.1 The International Civil Aviation Organization (ICAO) is the specialized agency the United Nations has designated to be responsible for establishing international standards, recommended practices and procedures covering the technical, economic, and legal fields of international civil aviation operations. ICAO is headquartered in Montreal, Canada. Most States are members. Canada and India are members.

2-2 Article 26 of the Convention on International Civil Aviation obliges States to institute an Aircraft Accident Inquiry in accordance with ICAO procedures. "Standards and Recommended Practices for Aircraft Accident Inquiries" were first adopted pursuant to

Article 37 of the Convention and were redesignated as Annex 13. Since the Air India Flight 182 occurrence took place in international waters, jurisdiction to conduct the aircraft accident investigation was the responsibility of the country of aircraft registry: India (refer to ICAO Annex 13).

2.3

The Government of Canada offered assistance to the Government of India, which was accepted. The Canadian Aviation Safety Board (CASB) provided some of that assistance and participated in the Government of India investigation as an Accredited Representative (refer to ICAO Annex 13).

CASB/TSB BACKGROUND

The CASB was created in 1984, by an Act of Parliament, as an independent federal government agency with the sole object of advancing aviation safety. It was not the object of the Board to determine or apportion any blame or liability in connection with aviation occurrences. The mandate of the CASB was to advance aviation safety by: conducting independent investigations and, if necessary, public inquiries into aviation occurrences (accidents, incidents, or safety hazards) in order to make findings as to their contributing factors and causes;

-I-

- *identifying safety deficiencies as evidenced by aviation occurrences-
- *reporting publicly on its investigations and public inquiries and on the related findings-
- *making recommendations designed to eliminate or reduce safety deficiencies.

3.2

The CASB was subsequently replaced by the Transportation Safety Board (TSB) of Canada. The TSB was created by an Act of Parliament which came into force on 29 March 1990. The TSB is also an independent federal government agency with a mandate similar to the CASB, but the area of responsibility were increased to include railway, marine, and commodity pipelines in addition to aviation. The TSB inherited the CASB aircraft accident investigation files, including the Air India Flight 182 file (CASB file number: 5002-85-F50903). The TSB has not carried out an investigation into Air India Flight 182.

4.0

C AVIATION INVESTIGATION (1985 TO 1980)

4.1

Activities such as search, recovery, and analysis of floating and submerged wreckage from Air India Flight 182 was undertaken in 1985, as part of the Government of India aircraft accident investigation. CASB participated in these activities (and others) as an Accredited

accident investigation

Representative. It should be noted that only a very small fraction of the aircraft was recovered. Subsequent RCMP AITF dive campaigns (referred to later in this report) recovered only a few additional pieces.

4.2

Internal CASB reports and correspondence were prepared on some aspects of the investigation. Copies of other reports and reference material (both domestic and foreign) were compiled by CASB (under CASB file number: 5002-85-F50903). This information was used by CASB to prepare a submission for the purpose of advancing aviation safety.

4.

During the Government of India investigation into the Air India Flight 182 occurrence, I was employed at CASB and participated in this investigation. My duties involved:

- o search and recovery operations,
 - . providing failure analysis assistance to the CASB investigation team,
 - . examining a few pieces of wreckage for post-blast damage,
- z'

o attendin- a small part of the Justice Kirpal Commission of Inquiry to provide technical advice on failure analysis and post-blast damage on a few pieces of wreckage to the CASB Investigator-in-Charge: Art LaFlamme.

5.0 ANALYSIS WORK FOR RCMP (1988 TO PRESENT)

5.1

In 1988, the RCNV requested aircraft accident investigation assistance from the CASB, as part of their on-going criminal investigation into Air India Flight 182. I was assigned to

-2-

The submission was made in India.

to carry out this work for the RCNP AITF. Work activities involved-

- o independent aircraft accident investigation review of the reports and files pertaining to the Air India Flight 182 occurrence,
- o mission planning and participation in the 1989 RCNU dive campaign,
- o participation in explosive sabotage tests conducted by the United States (US) Federal Aviation Administration (FAA) on a narrow body Boeing 707 aircraft in Tucson, Arizona in July 1989.

5.2

Through RCNW requests to the TSB, I have been seconded to the RCNT AITF to continue to provide aircraft accident investigation assistance for their on-going criminal investigation. Highlights of some of the work activities I was involved in follows:

- * continued independent aircraft accident investigation review of the reports and files pertaining to the Air India Flight 182 occurrence,
- * invited to and participated in the British Air Accidents Investigation Branch Boeing 747-121 Pan Am Flight 103 Lockerbie investigation in 1989,
- * participated in mission planning for the 1990 RCNT dive campaign (it was postponed),
- * did mission planning and participated in the 1991 RCNT dive campaign,
- * participated in the RCNV AITF visit to the Department of Civil Aviation Facilities in New Deh and the Air India Facility in Bombay in June, 1992, to examine all Air India Flight 182 wreckage stored in India,
- * participated in explosive sabotage tests conducted on a narrow body DC-10 aircraft by the RCMP in Carp, Ontario in October 1991,
- * reviewed other aviation occurrences and aircraft bombings for reference purposes during different intervals which were concentrated over the time frame from 1994 to 1997 (work continues to date),
- * reviewed FAA explosive sabotage tests results conducted on a wide body Boeing 747-100 aircraft, which was destroyed in Bruntford, North Carolina,

Leicestershire, England in May 1997,
*re-examined all wreckage in the possession of the RCNW AITF in Vancouver in July 1997,
*attended RCMP explosive sabotage tests conducted on the cargo compartment section of a wide body Boeing 747-200 aircraft in Tucson, Arizona in October 1997,
*attended explosive sabotage tests on a wide body Lockheed L-1011 aircraft in Mobile, Alabama in January of 1998,
*reviewed information on the Air France Flight 171 Boeing 747 aircraft occurrence, United States registration: N1252E, in May 1998,
examined personal effects of the victims with the RCNW AITF in February 1998.

5.3

My independent investigation work for the RCW AITF has been concentrated in two main areas:

Structural Break-up Analysis and, Trajectory/Wreckage Pattern Analysis.

A summary of this work is outlined in Sections 6.0 and 7.0 of the report. It should be noted that the Air India Flight 182 data I used for my work is primarily based on information gleaned from:

0 Kirpal Commission of Inquiry records,
0 CASB records (CASB file number: 5002-85-F50903),
0 data collected by the RCMP AITF and,
0 information on other aircraft occurrences, tests, etc., used for reference purposes.

5.4

In carrying out my work for the RCNIP AITF, two other TSB employees have, on occasion, provided some part-time assistance to myself. These individuals are:

Louis Landfiault

Mr. Landfiault primarily provided help in the design and operation of the Computer Aided Design/Drafting (CAD) and integrated database system used in this investigation (refer to Section 6.0 of the report).

Demetrios Karafotias

Mr. Karafotias primarily provided early CAD operator assistance such as creating some initial wreckage plots. He is no longer employed at the TSB.

5.5

Two private contractors hired by the RCNP have, over different contract periods, provided full-time assistance to myself during the Air India Flight 182 investigation. These individuals are:

. Jack Melson

Mr. Melson primarily provided early wreckage target identification and fracture pattern plotting.

. Ted Slack

Slack primarily provided follow-on wreckage target identification and fracture pattern plotting.

5.6

Arrangements were also made through the RCMP to obtain specialized CAD services from the Department of National Defence (DND) Quality Engineering Test Establishment (QETE). The DND QETE employee tasked to manage this work was:-

Fabian Allard
in

Mr. Allard was primarily responsible for converting two dimensional (2D) drawings of fracture patterns (produced by Mr. Melson and Mr. Slack) into three dimensional (3D) CAD model pieces. The I-Es group then added the exterior paint scheme of the aircraft onto the surfaces of these items.

5.7

Further assistance was also provided by the RCW. For example, a RCNT member of the Criminal Intelligence Directorate was assigned to provide long term local liaison and support. The individual assigned was:

Sgt. Terry Goral

Sgt. Goral was the primary contact who provided records and file information. He also assisted in organizing, checking and validating data.

6.0

STRUCTURAL BREAKUP ANALYSIS

6.1

Some of the data referred to in paragraph 5.3 was reorganized for analysis work. An example is the following imagery:

- *all available underwater photographs (colour negative/colour positive) and underwater videos from the 1985, 1989 and 1991 dive campaigns,
- *photographs taken during the AITF examination of recovered wreckage in New Delhi and Bombay in 1992,
- *photographs taken of wreckage in the possession of the AITF in Vancouver in 1997.

6.2

The imagery listed above was indexed and entered into a database which was linked to a Computer Aided Design/Drafting (CAD) system. The photographs (in excess of 5000 in number) were scanned onto Compact Disks (CDs). All the 1985, 1989 and 1991 videos were digitized onto Digital-S video cassettes (which numbered in excess of 75). The digitization process was undertaken to preserve as well as organize the imagery. Each video segment and each CD image were then linked, where possible, to a target number and logged into the database/CAD system. The CD imagery was run on computers equipped with software that could facilitate image processing operations. These operations were used to enhance the imagery as necessary to bring out fine detail through enlargement, contrast/brightness/edge/colour adjustment, etc. The computer was also linked to printers for hard copy output. The digital video was run on equipment that could be interfaced to computers so that electronic frame grabs could be taken of video imagery to create still pictures, as needed. The imagery was analysed to systematically trace out fracture patterns on engineering drawings. The fractures were located by plotting their relationships to engineering drawing details such as:

-5-

doors,
windows,
paint schemes,
skin cutouts and joints,
rivet patterns,
frames,

stringers,
beams, etc.

6.3

Work was concentrated on tracing out the fracture patterns of the positively identified parts that formed the exterior skin of the fuselage. In addition, positively identified pieces associated with the floor structure of the aft cargo and bulk cargo compartments were also traced out. The flooring work was undertaken to reconstruct this area in more detail since the exterior skin was more broken up in this region. Attempts were made to also reconstruct the passenger floor in the same vicinity, however, there was insufficient information available to complete this task.

6.4

The fracture patterns were transferred from 2D drawings to a scale, 3D- CAD model of the aircraft. By doing this work, the aircraft was systematically reconstructed in the computer in 3D. Each individual piece of wreckage drawn was correlated to its target number, and each could be color coded to designate from which Section of the aircraft it was associated with (refer to Appendix "N" for Section numbers and Station (STA) numbers). The following pieces of exterior fuselage and empennage (tail assembly) skin have been reconstructed, and transferred to the 3D aircraft model with the appropriate paint scheme (listed by target number from the front to the rear of the aircraft, in columns to be read from top to bottom, left to right):

"245" "358/399" cciiii '-26" c'9711 "6811 '419211 4'1 -1 7 11 "287" "656'f 4c7491 119911
"218" 4'2 8 11 '4011 "307" cc73 11 c'67" "204" "711 cc81' cc28211 "3 3 /-1 4 11 "2711 41 1
91 of 14 1 ft "loll, '4658'f 4'36911 5 11 ")62/-)9611 21 11 4'71 11 'c)20" c4-) 71 It c"37t'

6.5

Isometric views of the 3D aircraft model showing different combinations of detail are shown in Appendix "B". The exterior paint scheme on the model has been projected through onto the inside surfaces of the aircraft skin to better highlight details such as the location of windows, doors, etc. The outline of the cargo areas has been depicted by coloured LDI baggage containers, 88" x 125" pallets, and subdivided bulk cargo compartment floor regions. Cargo information is based on the aircraft load sheets and

91

other associated material. The layout of skin targets (referred to in paragraph 6.4) and the layout of the passenger floor plan (based on engineering drawing details and the passenger manifest) are also shown.

-6-

6.6

Appendix "C" shows different two dimensional views of the aircraft (top, left, bottom and right) with the outline of each skin target, which has been labelled with its target number. The targets in this Appendix are depicted without the aircraft paint scheme, and they have not been drawn in as fine a detail as that shown on the 3D aircraft model. The outline of some primary aircraft structure (e.g. stringers and frames) appear underneath the targets for reference purposes.

6.7

The outline of other targets that make up the aft cargo and bulk cargo compartment floor structure were drawn out in a similar manner. The floor pieces that were reconstructed (listed by target number from the front to the rear of the aircraft, in columns to be read from top to

bottom, left to right) are:

c'2f	c42511	'c653"
c'47'f	'c40ll	

(Note: Target "40" is in both the list above and the list in paragraph 6.4 because it is comprised of pieces from both the exterior fuselage skin, and from the aft cargo and bulk cargo compartments).

6.8

Appendix "D" depicts left and right side views of the aft fuselage showing the aft and bulk cargo compartments. It illustrates the spatial relationship of the skin targets to the pallets, baggage containers and the bulk cargo regions. Target "24" is also shown with these items. This target is a piece of the bac, a-e container situated at position 44R in the aft cargo compartment.

6.9

Appendix "E" is a top view of the aft and bulk cargo compartment floors showing different combinations of detail. It illustrates the spatial relationship of the skin and floor targets to the pallets, baggage containers and bulk cargo regions.

Breakup Analysis of the Forward Half of the Aircraft Fuselage (Sections 41, 42, 44)

6.10

It should be noted that systematic analysis of each piece of wreckage for both the forward and rear halves of the aircraft did not reveal any evidence of any malfunction or pre-existing defect that may have been contributory to the occurrence. The fractures and fracture patterns examined were all consistent with an overload mode of failure.

6.11

Breakup analysis of the forward half of the aircraft fuselage (Sections 41, 42 and 44) disclosed that it had fractured into large segments (e.g. targets: "192", "4'218'f", "I'7") which were found lying in large crumpled piles or heaps, smaller pieces of wreckage tended to be found in concentrated clusters or groups of items,

-7-

the interior was often found entrapped, entangled, attached, or in close proximity to the exterior skin and structure which initially enveloped it (this was particularly evident in the large segments previously referred to).

Detailed examination revealed that in Sections 41, 42 and 44 items such as aircraft furnishings, insulation, wiring, seats, floor structure, and fuselage frames were often found still fixed to and/or crushed/pinned within these heaps, or they were found in close proximity to them. It should be noted that the size of some of the large segments of the aircraft could not be fully delineated by tracing the fracture patterns since some areas were partially buried and/or were hidden from view. Consequently, some reconstructed portions of the aircraft are lacking data in some areas, and therefore represent conservative estimates of the overall extent of the pile or chunk. Examples of this are seen in targets "192" (Section 41), "218" (Section 42) and "137" (Section 44).

6.12

The general appearance of the piles or chunks (referred to in paragraph 6.1.1) indicated that these portions of the aircraft struck the water predominantly intact. For example, the exterior skin of the lower portion of the nose of the aircraft shows evidence where it has been sandwiched on impact. The skin is badly flattened from being crushed by the internal debris, and dished inward by the water impact forces on the other. This structure on one side was seen on target "245" (Section 41).

Similarly, the fuselage portion above the wing centre section (target "IJ7") has essentially remained as one massive piece. This piece was still attached to a considerable portion of the upper wing.

Breakup Analysis of the Rear Half of the Aircraft Fuselage (Sections 46 and 48)

6.13

Breakup analysis of the rear half of the aircraft (Sections 46 and 48) disclosed that in contrast to the front half of the aircraft: the structure had fractured into smaller pieces, the overall extent of fragmentation was greater, the pieces were typically found lying alone, isolated from one another the interior was characteristically stripped away from the exterior skin and the structure which initially enveloped it.

Examination disclosed that the vast majority of exterior skin from the rear of the aircraft was essentially bare, devoid of interior items such as furnishings, insulation, seats, etc. Analysis revealed that a sudden and distinct change between the two different types of fuselage breakup patterns occurred at fuselage Station (STA) 1480. This location corresponds to the manufacturing joint between fuselage Sections 44 and 46. It is located just behind the wings of the aircraft. The forward end of the aft cargo compartment is located at a bulkhead at this location. The area of the Joint was found to have completely fractured in two. The fracture at STA 1480 is considered significant since'

-8-

it generates a clear dividing line between the two different breakup patterns observed.

6.14

It was previously noted that the rear of the aircraft was much more fragmented. The extent of fragmentation generally increased from STA 1480 aft until the vicinity of STA 2400, where large pieces of the empennage were encountered (e.g. fin, horizontal stabilizers). The largest pieces of wreckage in the rear of the aircraft were situated adjacent to STA 1480 (refer to target "28"), and adjacent to STA 2400 at the empennage (refer to targets "31" and "37"). On the left side of the vertical fin (target "37") was delineated by tracing the fracture patterns since the right side was partially buried and/or hidden from view. The fin was found lying on its right side on the ocean floor. Consequently, this delineation represents a conservative estimate of the overall extent of the fin.

6.15

The breakup of the aft cargo and bulk cargo compartments in the rear half of the aircraft were found to be unique. As such, they will be discussed separately below.

Breakup Analysis of the Aft Cargo and Bulk Cargo Compartments

6.16

The manner in which targets from this area separated is considered to be significant. The targets of specific interest are:

Target "7",
Target "8",
Target "47",
Target "307",

and other targets which exhibit deformation patterns.

Target "7"

6.17

Target "7" is a large piece of belly skin from the aft cargo compartment, along the aircraft centerline. It is approximately 32 feet in length and approximately 8 feet in width. It extends

from STA 1480, which is the forward end of the aft cargo compartment, to approximately STA 1860. It extends almost the full length of the aft cargo compartment. The compartment ends at STA 1920. The keel beam extension booms are attached at one end near STA 1480. The sides of this piece of skin generally follow stringers 45L and 45R.

6.18

Target "7" exhibits key characteristics that are considered to be very significant. The large piece of skin that makes up this target is clearly separated from the ends of all the frames it was attached to without being grossly deformed or disfigured (e.g., bent, twisted, crushed) over the vast majority of its surface area. There were three regions that did exhibit some localized deformation. These regions were situated at the periphery at the right side where some curling of sheet metal took place near STA 1540 and STA 1760, and at the

-9-

end of target "7" near STA 1860. It is significant to note that the frames on target "47" that mate to the skin on target "7" were also found to be in very good condition, as were the other pieces of the floor assembly on target "47" (refer to paragraph 6.24).

Examination of the fracture patterns indicated that the skin and frames had been pulled apart in overload. The manner in which they were pulled apart (leaving both the skin and floor structure in such good condition, over such a large area) is unique. This is not characteristic of aerodynamic or impact damage. The only type of loading that could conceivably generate this type of failure is internal overpressure load(s) acting on the inside surface of the belly skin, pushing the skin outward away from the frames.

The regions where localized deformation took place were found to also be consistent with this mode of failure (refer to deformation patterns in paragraph 6.28). It is significant to note that the local deformation that took place at the end of target "7" near STA 1860 was also present on target "8" (refer to paragraph 6.22).

6.19

Another unique feature observed on target "7" was the overload failure of the keel beam splice joints situated near STA 1480. The keel beam is one of the strongest parts in the aircraft. It forms the foundation upon which the aircraft structure is built. The keel beam extends across the centre of the body gear wheel well in the aircraft centre section. Two booms are attached to the keel beam by splice joints near STA 1480. These booms extend aft along the underside of the aircraft and are rivetted to the belly skin of target "7". The overload failure of the splice joints is significant because of the enormous load required to break them and, the joints were broken without imparting any significant gross deformation damage to the belly skin they were attached to.

6.20

Yet another unique feature was observed on target "7". A sinusoidal displacement along the fractured left edge of the skin (near stringer 45L) was found to have taken place. In my entire career, I have never observed this phenomena on a piece like this except in one instance, which I will describe in paragraph 6.21. I have consulted with my aircraft accident investigation colleagues in other governments (e.g. AAEB, NTSB) and in industry. To date, I have found no one who has seen this phenomena on a piece like this elsewhere in any aircraft accident cases.

6.21

The only instance where I have found a similar example of a sinusoidal displacement on a piece like target "7" was when I examined photography and video of a piece of fuselage skin from the Bruntingthorpe 747-100 destructive bomb tests. I have observed in another instance, pieces which bore a resemblance but the amplitude of the sinusoidal pattern was not as pronounced. This

occurred when I examined pieces of aircraft wreckage from the Mobile LI 0 1 1 destructive bomb tests.

-10-

Target "8"

6.22

Target "8" is a piece of belly skin that mates to the end of target "7" at STA 1860 and extends to approximately STA 1960. About half of the length of this piece of skin is situated below the luggage containers at position 44R and 44L (at the aft end of the aft cargo compartment), and the other half is situated below position 51 (at the forward end of the bulk cargo compartment). The sides of this piece of skin generally follow stringers 46L and 47R.

6.23

Target "8" is considered significant because it also exhibited separation of all of the frames from the belly skin, like target "7". It too is consistent with having been generated by internal overpressure load(s). Targets "7" and "8" essentially comprise most of the belly skin below the floor of the aft cargo compartment. The deformation and degree of damage on target "8" was much greater than target "7".

Target "47"

6.24

Target "47" is a piece of cargo compartment floor and floor support structure. It extends from approximately STA 1590 to approximately STA 1770. This piece basically spans most of the width of the aft cargo compartment from stringers 45L to 41R. It is predominantly situated below the pallets at position 32P and 41P, in the nu'd portion of the aft cargo compartment. It is comprised of approximately 9 frames which mate to the skin of target "7".

6.25

Target "47" is considered very significant because it also exhibited a clean separation of all its frames that mate to the belly skin of target "7". The frames were found to be in very good condition, as were the other pieces of the floor assembly on it such as roller trays, retractable drive wheels, etc. The thin frangible sections of the frames exhibited minimal damage and were not significantly deformed (e.g. bent, twisted, squashed). These characteristics are also consistent with having been generated by internal overpressure load(s).

Target "307"

6.26

This item is a piece of exterior skin located from approximately STA 2060 to approximately STA 2220, and from approximately station 28L to approximately station 42L. It forms part of the bottom and left side of the bulk cargo compartment. This piece was recovered during the RCMP 1989 dive campaign.

6.27

Some frames had cleanly separated from the skin. The skin exhibited bulges in an outward direction in between rivet lines, creating a "quiltin-" pattern. Small depressions were also present around rivet holes, which appeared consistent with damage caused by the rivets either being pulled through the skin or failing in tension after they had plastically deformed

-II-

the skin. The "quilting" and pull through effect of rivets are considered consistent with damage

caused by internal overpressure load(s).

Deformation Patterns

6.28

The plastic deformation of individual pieces of fuselage skin from both the forward and rear halves of the aircraft were studied (pieces analysed are listed in paragraph 6.4). Outward bulging of the skin and/or the presence of petals or curls in the sheet metal of the skin were found on some targets. For the purposes of this report, petals or curls are defined as the shape formed when pieces of skin have been plastically deformed in an outward direction, such that a continuous curve or near continuous curve is generated, producing a roll or part of a roll in the sheet metal. The radius of curvature typically is not constant.

6.29

Although it is possible for outward bulging of the skin and petals or curls to be made in sheet metal in some instances by aerodynamic forces during breakup or due to water impact, analysis indicated that a significant number of deformations found in the rear half of the aircraft were not associated with these types of events. An ordered and well integrated, not random, pattern was found in the rear half. This was in contrast to the forward half of the aircraft where deformation was found to be primarily associated with impact damage.

6.30

In the rear half of the aircraft numerous pieces of exterior skin on the bottom and both sides of the fuselage were found to be deformed in a manner consistent with them having been peeled or rolled outward, away from the aft cargo and bulk cargo compartment areas. Outward bulging of the skin was also present on some targets. For example, targets such as "287", cc65811, "26" and "69" on the left side of the aircraft, and corresponding targets c'321 ", "71 " and "282" on the right side showed some of these characteristics. The sheet metal of some of these targets exhibited petals and curls consistent with having been pushed outward, and in a general direction upward, toward the window lines of the aircraft, and/or some outward bulging of the skin was present. This overall pattern is considered significant. It is consistent with: damage generated by the rupture and venting of internal overpressure outward from the aft cargo and bulk cargo compartment areas.

Aircraft Pressurization

6.31

It should be noted that most of the aircraft fuselage is a pressure vessel. Except for the nose gear and main landing gear wheel wells, and the centre wing structure, the fuselage from STA 140 to STA 270 is pressurized when the aircraft is in cruise flight. Regulation of pressure is primarily accomplished by controlling the size of the openings of outflow valves, through which ventilation air escapes from the aircraft. Failure of the aircraft

-12-

pressurization system was studied to see if a malfunction of this system could create rapid overpressurization in the fuselage. No scenario could be conceived that was consistent with the evidence in this case.

6.32

Detonation of a bomb (improvised explosive device) in the aft cargo compartment or bulk cargo compartment could generate sudden, large, overpressure pulses. These overpressure pulses could distribute large loads on numerous inside surfaces almost simultaneously. The layout of the lower fuselage is such that only a thin curtain separates the aft cargo compartment from the bulk cargo compartment. Both these compartments are interconnected. Cargo load information indicates that

there were only two luggage containers in the aft cargo compartment (at positions 44L and 44R), and that four open pallets containing engine parts and cowlings were forward of these containers. There would have been open airspace around the pallet locations. Hence, air pressure associated with blast effects could be transferred around the pallets, and onto the bulkhead at the front of the aft cargo compartment (at STA 1480). Post-blast overpressure effects could transfer tremendous loads to the keel beam joints at this location. If the 44L and 44R luggage containers and the bulk cargo curtain were breached, air pressure could more easily be transferred to the aft cargo compartment, and vice versa. Veliting of post-blast overpressures could generate petals and curls as well as outward bulging in the aircraft skin. The structural damage analysed exhibits similarities to the damage created by the Bruntingthorpe 747-100 destructive bomb (improvised explosive device) tests.

Structural Breakup Analysis Summary

6.33

Analysis indicated that the aft cargo and bulk cargo compartments failed due to large, internal, overpressure load(s). The only plausible way to do this rapidly, and in the manner previously described, is by the detonation of a bomb (improvised explosive device). The evidence I have examined is consistent with this.

7.0

TRAJECTORY[WRECKAGE PATTERN ANALYSIS

7.1

An analysis of the trajectory of the wreckage was undertaken to see if pattern(s) were present in the debris field. This work was not undertaken with any intent of, nor should it be misconstrued to be capable of, defining the exact or precise location where a particular part will come to rest. The work was conducted to analyse the general location where parts should fall (for certain given conditions) compared to the location where parts were found. It should be noted that the breakup of an aircraft in-flight involves numerous complex reactions and interactions, some of which may be random in nature. A wide variety of wreckage pieces will be created during the break-up which vary in weight, size, shape, etc. The behaviour of these parts as they fall through the atmosphere, and descend through the ocean (approximately 6700 feet in depth) in this case, cannot be precisely determined since there are simply too many unknowns, and too many variables. For example, the exact characteristics of the atmosphere and the ocean at the time of the occurrence (such as the direction and speed of the winds and/or currents) are not known,

7.2

If it is presumed that the manner in which all the wreckage was deposited on the ocean floor is meaningless because it is hypothesised that some unpredictable mixing of the wreckage has taken place (e.g. due to random events and/or due to the complexity of the situation), then the pattern of the parts on the ocean floor should show this. Conversely, if the wreckage has been deposited on the ocean floor in an ordered way that fits the laws of science in a predicted manner, then the pattern of the parts on the ocean floor should also show this. In order to determine which may apply in this case, I carried out my analysis.

7.3

The primary source of positional data I used in my analysis comes from the original 1985 aircraft accident investigation material, and from the RCMP AITF 1989 and 1991 dives (refer to Appendix "F" for samples of the data). The 1985 positional data was used to relocate targets during the RCW AITF 1989 and 1991 dive campaigns. The 1985 positions of the wreckage were found to be in general agreement with the positions measured in 1989 and 1991. All available data associated with the Air India Flight 182 dive campaigns (including the most recent ones) were reviewed, and relevant portions were indexed and correlated in a database. The

identity of each part was log-ed, related to where on the aircraft it had come from, and each was colour coded to designate from which section of the aircraft it was associated with. Efforts were concentrated on wreckage classified as positively identified. The location of each piece of wreckage on the ocean floor was plotted using Computer Aided Design/Drafting (CAD) software linked to the database. By doing so, different permutations and combinations were able to be queried in the database and the results were able to be graphically displayed, and output.

7.4

Some key points I used in my analysis (based on my independent review of the case) are:

1. the aircraft was proceeding normally at a constant airspeed and altitude toward the East (essentially along the 51° 35' North line of latitude) prior to the occurrence,
2. something sudden, without warning, and catastrophic in nature occurred,
3. no evidence was found of any malfunction or pre-existing defect that may have been contributory to the occurrence,
4. meteorologic information indicated that a mainly West or West North West airflow covered the area at the cruise altitude, surface winds were forecast to generally be Westerly, no significant meteorological reports (sigmets) were valid for the area at the time of the occurrence,
5. submerged wreckage came to rest on an essentially flat, featureless, ocean floor,
6. submerged wreckage was surveyed to determine the location of each part on the ocean floor, and parts were identified to determine where on the aircraft they had come from.

-14-

7.5

The wreckage field found on the ocean floor was generally oblong in overall shape, roughly orientated in a Northwest to Southeast direction. It was approximately 14 kilometres long from the first isolated target found at the most Westerly location (target

"IX": a tom suitcase at position 51° 02.63' North, 120° 53.12' West) to the last item at the Eastern end of the debris field. However, most of the wreckage was in an area that measured approximately 10 1/2 kilometres long by approximately 2 kilometres wide. There was a cluster of items to the North of the main body of wreckage, most of which are contained in an area that measured approximately 1 kilometre square (refer to Appendix "I&" for an overall wreckage plot)

7.6

Analysis of the wreckage revealed that concentrated heavy mass items (e.g. engines) were situated in the cluster of parts in the Northern portion of the debris field. Given the flight direction of the aircraft, these items (which conceptually act like cannon balls) define a base point for the trajectory analysis. Current and/or wind would have little effect on their trajectory path since they exhibit a lot of inertia (ie. once in motion, they want to remain in motion). When positively identified fuselage targets were plotted (by aircraft Section number), and colour coded to identify what portion of the aircraft they had come from, two distinct wreckage trails were evident. There was a slight overlap of a few pieces of each trail, which may have occurred due to factors such as the close proximity of one trail to the other. Both wreckage trails were orientated in an East South East direction (with light items predominantly deposited at the East South East ends of the trails). This indicates that the predominant wind/current drift line was to the East South East. This is consistent with a West North West airflow which defines the asymptote for each wreckage trail.

7.7

The first wreckage trail off the aircraft track was comprised almost exclusively of pieces from the rear half of the aircraft (e.g. Section numbers 46 and 48). This will be referred to as the Southern trail (coloured green). Since this trail was the first trail encountered off the aircraft track, the

trajectory analysis indicates that these items were the first group of parts to separate from the aircraft. The second wreckage trail was comprised almost exclusively of pieces from the front half of the aircraft (e.g. Section numbers 41, 42, and

44). This will be referred to as the Northern trail (coloured red). Since this trail was the second trail encountered off the aircraft track, the trajectory analysis indicates that this group of items separated from the aircraft as a second, separate event, after the first. In other words, the analysis indicates that the aircraft broke up in-flight in two major stages (refer to Appendices "H" and "I"). Parts comprising the Northern wreckage trail were found to be forward of the STA 1480 break, and parts comprising the Southern wreckage trail were aft of this break.

7.8

Trajectory analysis of the geographic distribution and concentration of wreckage indicated that the Southern green trail (Sections 46 and 48; rear half of the aircraft fuselage) was much more individually deposited as separate items, and spread out than the Northern red

-15-

trail (Sections 41, 42, and 44- forward half of the aircraft fuselage). As previously noted in the structural breakup analysis section of this report (refer to Section 6.0), the forward half of the aircraft fuselage had fractured such that it tended to be in larger, more complete chunks, clumps, or clusters of parts. In addition, more of the interior of the forward half was found intermixed or contained within exterior pieces of the skin as exemplified by targets "192", "218", and "137". This was in contrast to the rear half of the aircraft where the interior tended to be stripped away. From a trajectory analysis perspective, these findings are consistent with the structure of the rear half of the aircraft being much more extensively broken up at altitude and scattered, than the forward half of the fuselage.

7.9

It is significant to note that the very first item found (the most Westerly part) was a tom suitcase (target "1A!"). This suitcase was situated approximately 3 1/2 kilometres West from the Western edge of the main debris field. Since it was found so early along the flight path, it is consistent that this is one of the very first items to have separated from the aircraft. In order for this to take place it is likely that an opening in the fuselage occurred at a location where a suitcase was in proximity to the opening, such as in the vicinity of a cargo compartment or overhead locker (if an item of this type would have been allowed to be taken into the passenger compartment as carry-on luggage). In addition, some of the first items to be found at the beginning of the Southern trail were targets "8" (piece of belly skin below the aft end of the aft cargo compartment, extending to the forward end of the bulk cargo compartment), target "7" (large piece of belly skin below the aft cargo compartment) and target "2" (piece of cargo compartment floor from the aft cargo compartment). Based on the trajectory analysis, evidence indicates that the suitcase probably came from the rear of the aircraft, since the first off Southern trail of wreckage was comprised almost exclusively of pieces from the rear of the aircraft. Early breakup of the bulk cargo and aft cargo compartments was indicated by the early presence of targets "6811", "7" and "2" at the beginning of the trail.

7.10

It is significant to note that the wreckage trail patterns bear a very strong resemblance to a known case involving the same type of aircraft, at essentially the same altitude and speed, which was proceeding normally when, without warning, something sudden and catastrophic occurred. In this reference case, there was also no evidence found of any malfunction or pre-existing defect that may have been contributory to the occurrence. The case I am referring to is the Pan Am Flight 103 occurrence (refer to United Kingdom Department of Transport, Aircraft Accident Report 2/90, "Report on the accident to Boeing 747-121, N79PA at Lockerbie, Dumfriesshire, Scotland on 21 December 1988" There is an important distinction between the Air India Flight 182 and Pan Am Flight IO')

C,

cases. The distinction is that the wreckage trail patterns indicate that the lead Air India Flight 182 breakup event occurred in the rear of the aircraft, as opposed to the front in the Pan Am IO' case.

-16-

Trajectory/Wreckage Pattern Summary

7.11

Trajectory/wreckage pattern analysis indicated that the aircraft broke up in-flight in two major stages that occurred in sequence. Evidence indicates that the sudden, lead, catastrophic event was associated with the early, extensive destruction of the rear half of the fuselage. The breakup of the aft cargo and bulk cargo compartment areas played a key role in this event.

8.0

SYNOPSIS

8.1

The aircraft was proceeding normally when, without warning, something sudden and catastrophic in nature occurred.

8.2

No malfunction or pre-existing defect that may have been contributory to the occurrence was found.

8.3

Trajectory/Wreckage Pattern analysis indicates that the aircraft broke up in-flight in two major stages that occurred in sequence, creating the first off Southern wreckage trail and the secondary Northern wreckage trail.

8.4

The composition of parts in the first off Southern wreckage trail indicated that the lead catastrophic event was associated with the early, extensive destruction of the rear half of the fuselage (Sections 46 and 48). The composition of parts in the Northern wreckage trail indicated that the front half of the aircraft (Sections 41, 42, and 44) broke up later in the sequence.

8.5

The presence of the following targets at the beginning of the first off Southern wreckage trail indicated that the early, extensive destruction of the rear half of the fuselage was initially associated with the breakup of the aft cargo and bulk cargo compartment areas:

*Target "8": a piece of belly skin below a portion of the aft and bulk cargo compartments,

0Target "7": a large piece of belly skin below the aft cargo compartment and,

0Target "2": a piece of aft cargo compartment floor and floor support structure.

8.6

Structural Breakup Analysis disclosed that in contrast to the front half of the aircraft where it had fractured into large segments which were found lying in large crumpled piles or heaps with the interior often found entrapped, entangled, attached or in close proximity to the exterior skin and structure which initially enveloped it-, the rear half of the aircraft was much more fragmented into smaller pieces which were typically found lying alone, isolated from one another with the interior characteristically stripped away from the exterior skin and structure which initially enveloped it.

17-

8.7

Structural Breakup Analysis disclosed that the unique manner in which target "7", target "8", and target "47", failed in overload is consistent with all these failures having been caused by large internal overpressure load(s).

8.8

The presence of a unique sine wave on target "7" is consistent with having been generated by sudden, internal overpressure pulse(s).

8.9

The enormous load required to break the keel beam splice joints situated near STA 1480, and the manner in which these joints were broken in overload without imparting any significant deformation damage to the belly skin they were attached to, are consistent with damage generated by large, internal overpressure pulse(s).

8.10

The outward bulging of skin in between rivet lines which created a "quilting" pattern on target "307" is consistent with damage caused by internal overpressure load(s).

8.11

The overall deformation pattern of the exterior skin on the bottom and both sides of the rear fuselage, which exhibited petals or curls and the outward bulging of structure, is consistent with damage generated by the rupture and venting of internal overpressure(s) outward from the aft cargo and bulk cargo compartment areas.

9.0

CONCLUSION

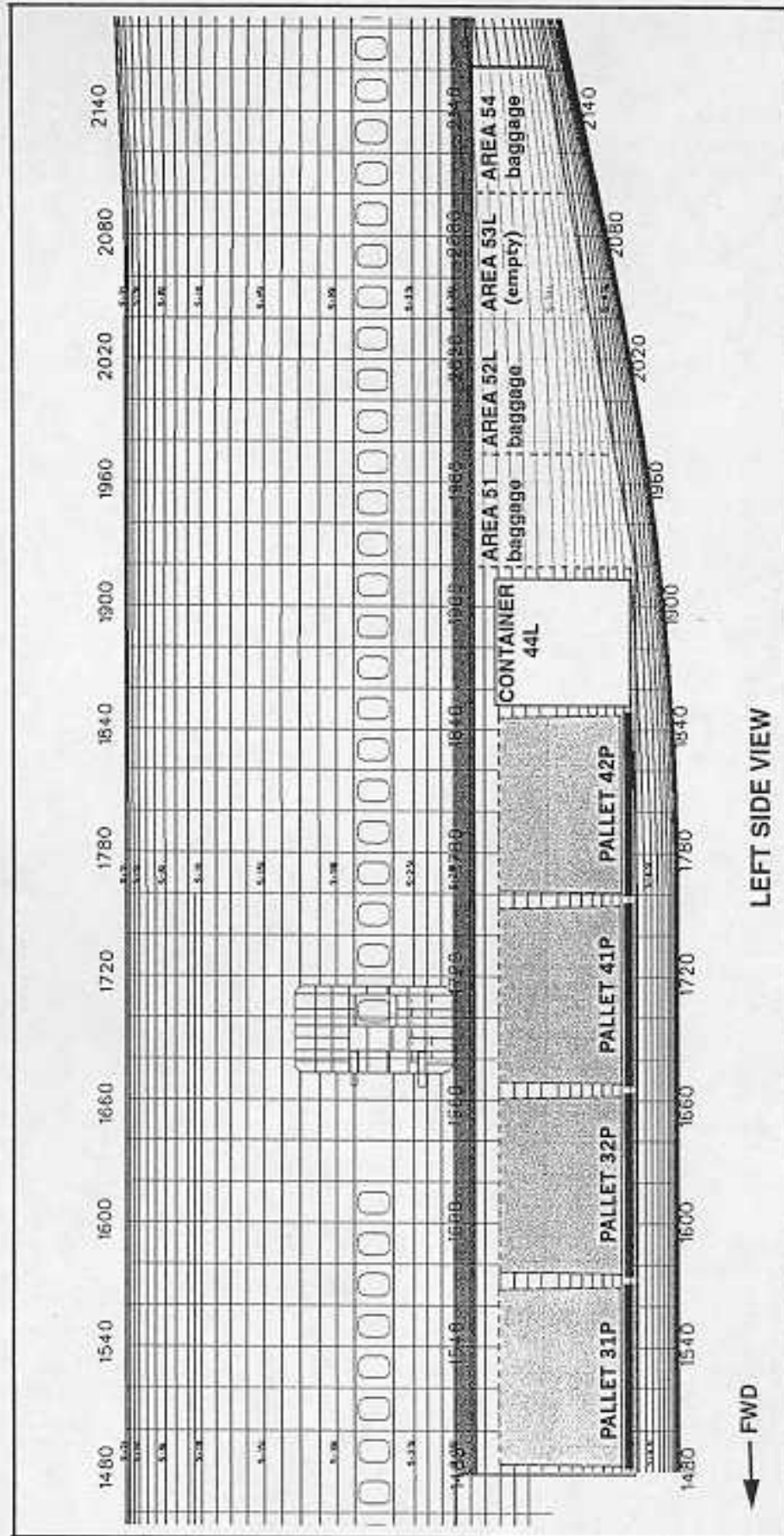
9.1

Analysis indicates that the sudden and catastrophic loss of the aircraft was due to the overload failure of the aft cargo compartment and the bulk cargo compartment as a result of sudden, large, internal overpressure load(s). The only plausible way to do this rapidly, and in the manner previously described, is by the detonation of a bomb (improvised explosive device). The evidence I have examined is consistent with this.

SECTION BREAKDOWN SECTION ERS NOMENCLATURE 7-11 Inboard Engine Strut
7-12 Outboard Engine Strut 7-13 Engine and/or Cowling 11 Center Section 12 Wing Panel
14 Leading Edge Flaps 15 Spoilers 16 Trailing Edge, Flaps, Inboard and/or Outboard 17
Ailerons, Inboard and Outboard 18 Wing- Tit) 41 Body Section (STA 90 to STA 520) 42
Body Section (STA 520 to STA 1000) 44 Body Section (STA 1000 to STA 1480) 46 Body
Section (STA 1480 to STA 2360) 48 Body Section (STA 2360 to STA 28')2) 61 Main
Landing Gear - Wing 62 Nose Landing Gear 63 Main Landing Gear - Body 81 Stabilizer
Torque Box 82 Stabilizer and/or Tip 8 @) Stabilizer Leading Edge 84 Elevators, Inboard
and/or Outboard 85 Dorsal Fin 86 Vertical Fin Assembly 87 Vertical Fin Leading Edge 88
Rudders, Upper and/or Lower

Note:For the purposes of this report, empennage (tail assembly) pieces that comprise Section
Numbers 81 to 88 will be grouped with Body Section Number 48 (as per reports prepared for
the Kirpal Commission of Inquiry),

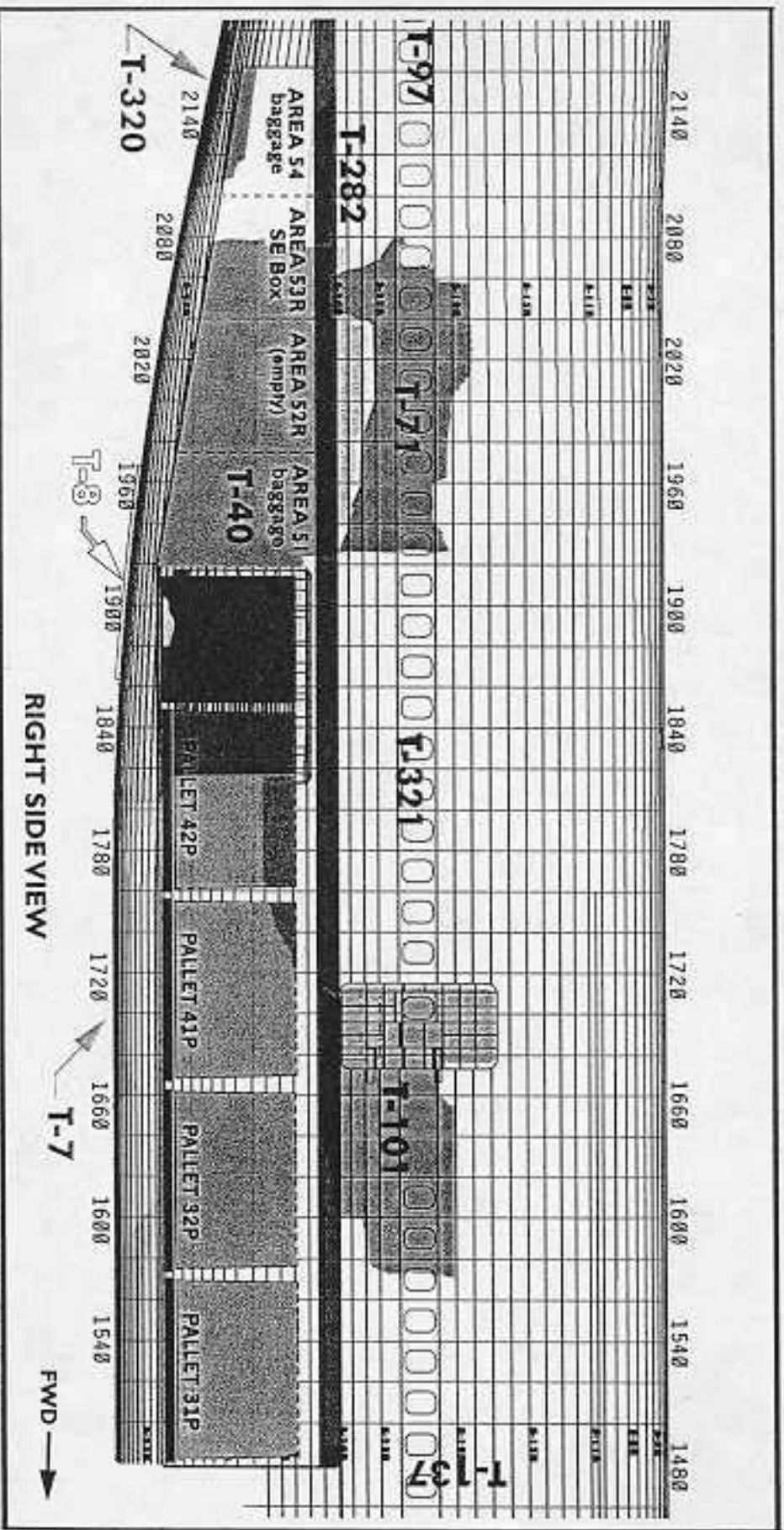
**AFT FUSELAGE SHOWING SKIN TARGETS,
PALLETS, BAGGAGE CONTAINERS
AND BULK CARGO REGIONS**



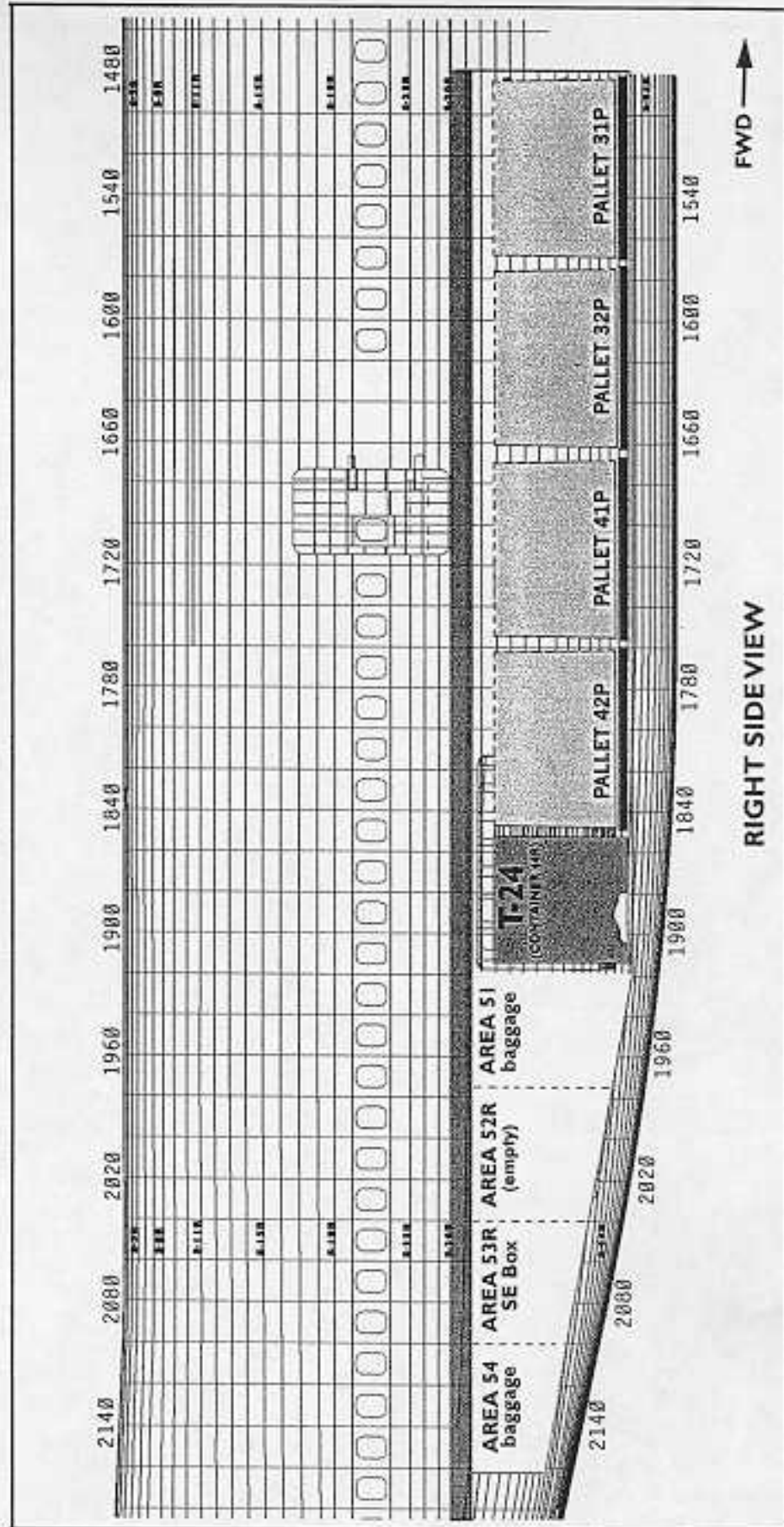
LEFT SIDE VIEW

← FWD

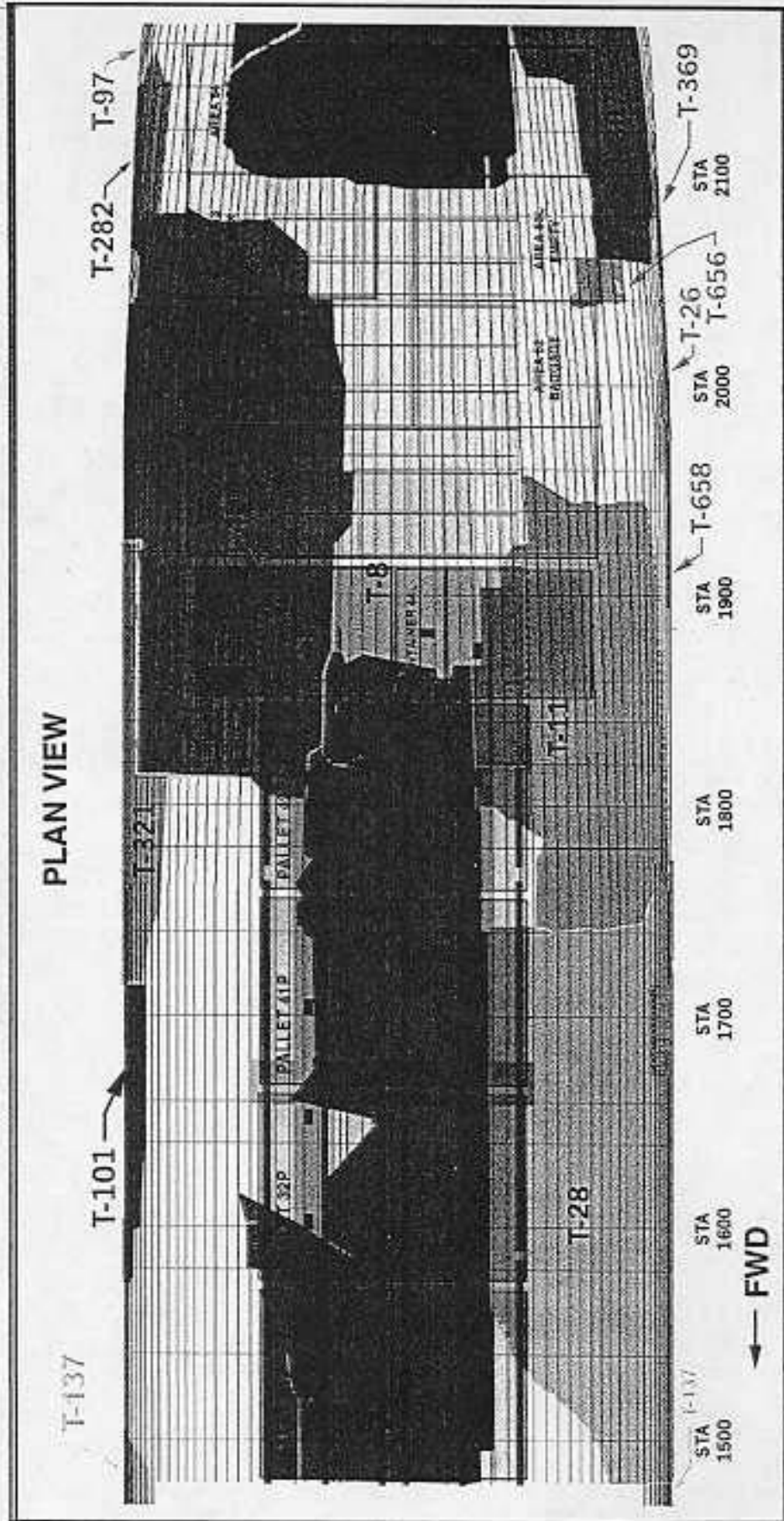
**AFT FUSELAGE SHOWING SKIN TARGETS,
 PALLETS, BAGGAGE CONTAINERS
 AND BULK CARGO REGIONS**



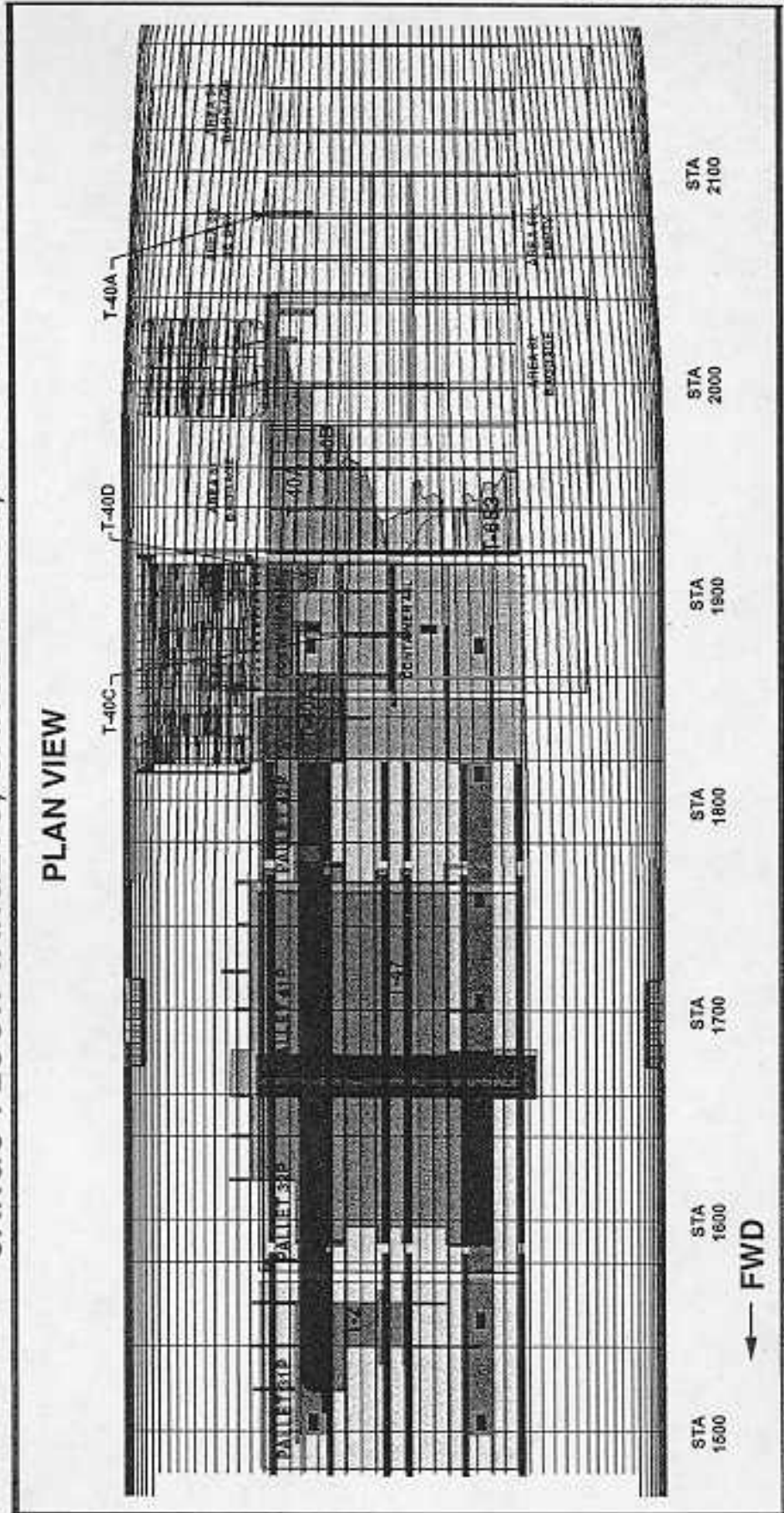
**AFT FUSELAGE SHOWING SKIN TARGETS,
PALLETS, BAGGAGE CONTAINERS
AND BULK CARGO REGIONS**



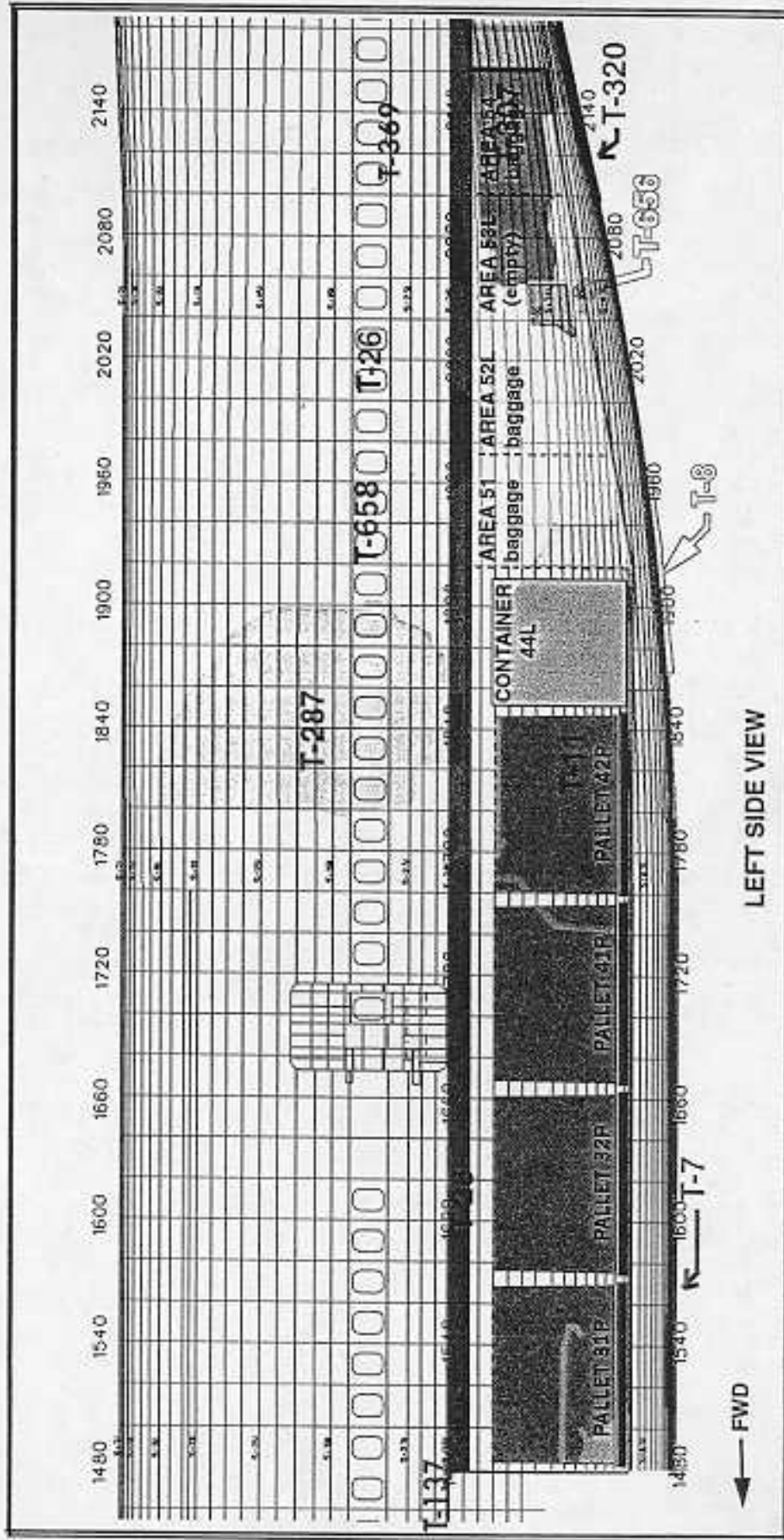
AFT CARGO AND BULK CARGO COMPARTMENTS
WITH
FUSELAGE SKIN TARGETS, CARGO FLOOR, AND CARGO



**AFT CONTAINER AND BULK CARGO AREA
WITH
CARGO FLOOR TARGETS, CARGO FLOOR, AND CARGO**

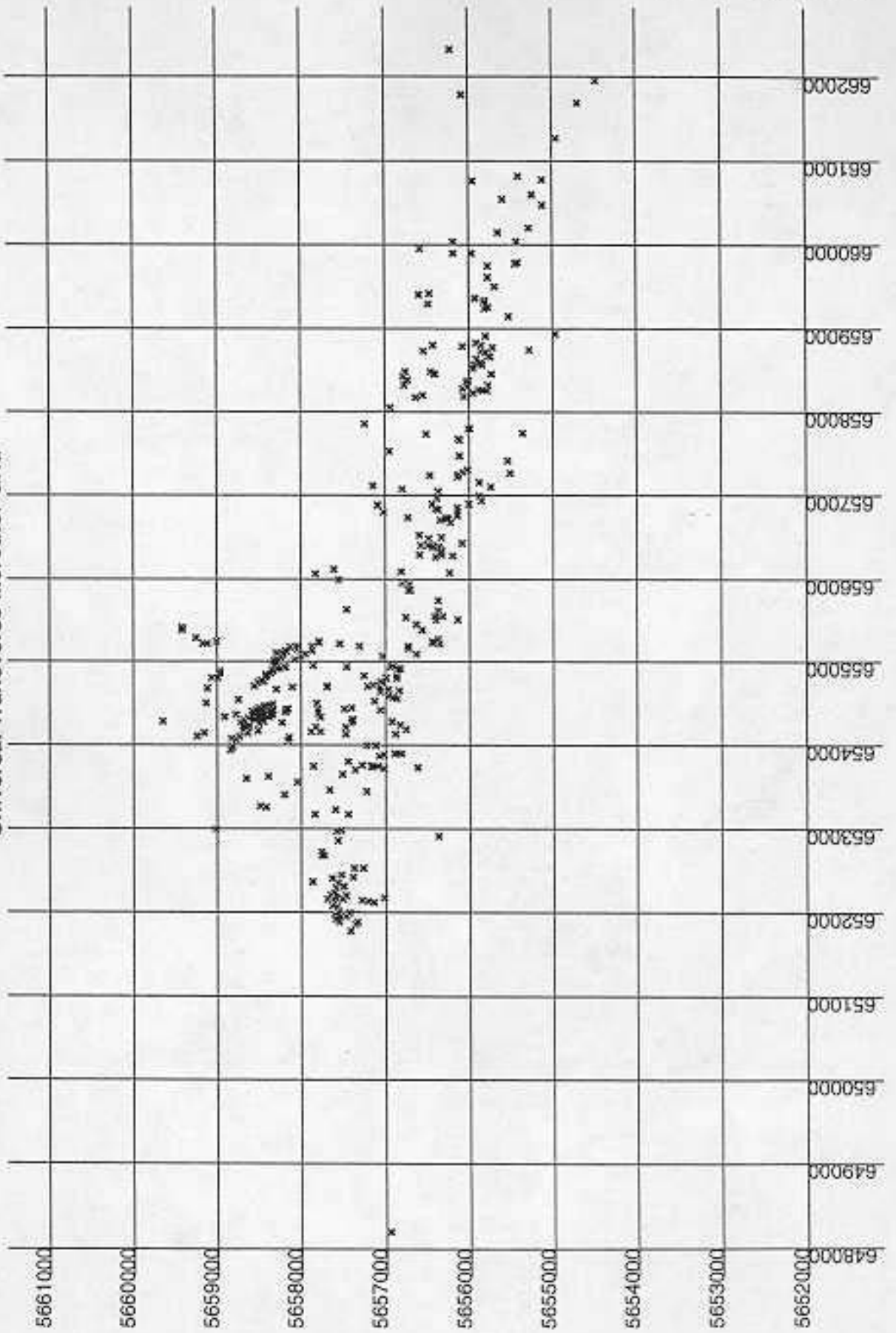


**AFT FUSELAGE SHOWING SKIN TARGETS,
PALLETS, BAGGAGE CONTAINERS
AND BULK CARGO REGIONS**

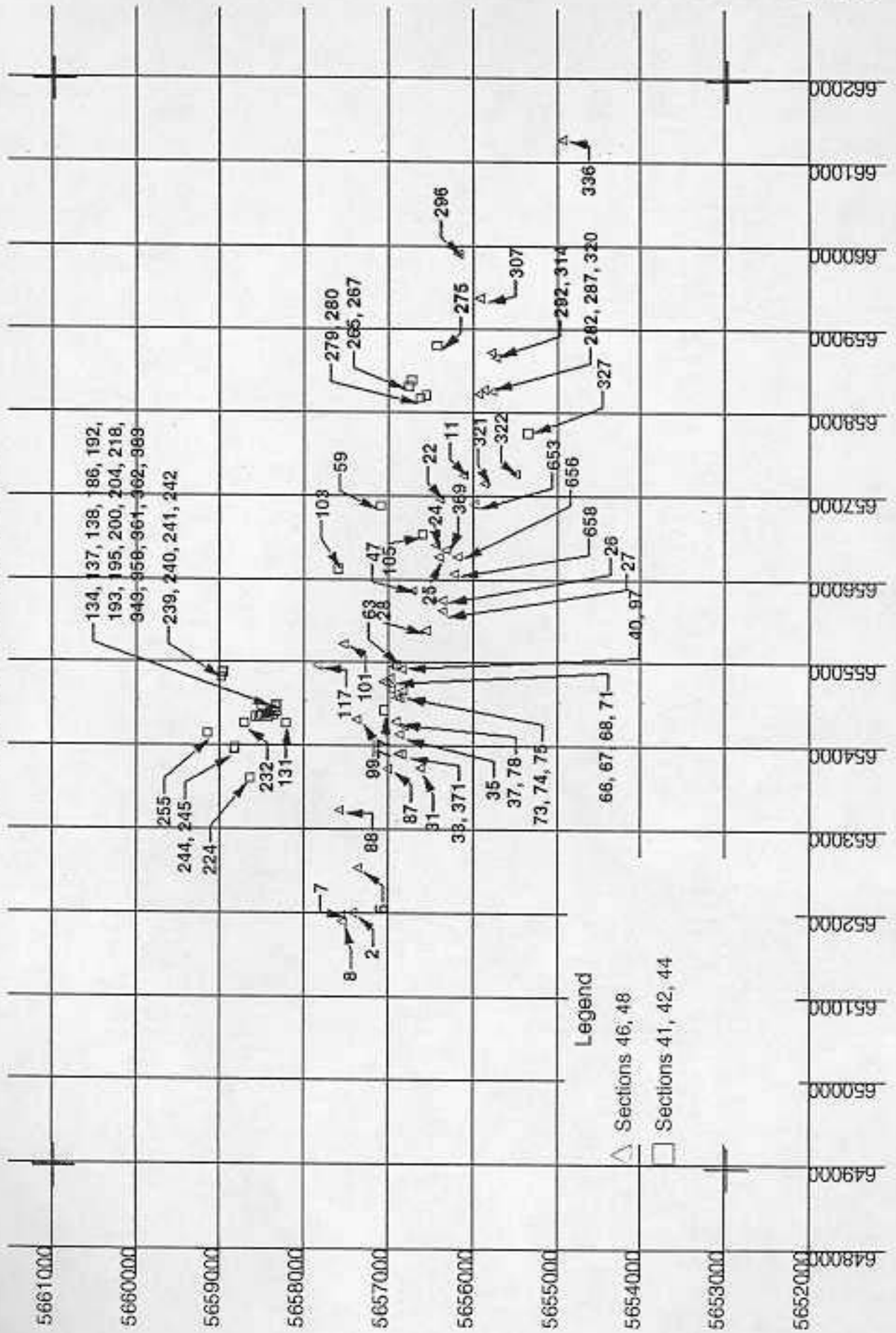


APPENDIX G

Plot of All Targets
Universal Transverse Mercator Grid



Plot of Targets: Northern & Southern Wreckage Trails
 Universal Transverse Mercator Grid



Legend
 △ Sections 46, 48
 □ Sections 41, 42, 44

Plot of Targets: Northern & Southern Wreckage Trails, Engine & Wing Parts, 1st Item Found
 Universal Transverse Mercator Grid

