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STRUCTURES GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, DC 20594

February 20, 1997

STRUCTURES GROUP CHAIRMAN'S FACTUAL REPORT

DCA-96-MA-070

A. ACCIDENT

Location	**:**	**East Moriches, New York**
Date	**:**	**July 17, 1996**
Time	**:**	**2031 Eastern Daylight Time**
Aircraft	**:**	**Boeing 747-131, N93119**
		Operated as Trans World Airlines (TWA) Flight 800

B. STRUCTURES GROUP

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C. SUMMARY

On July 17, 1996, at 2031 EDT, a Boeing 747-131, N93119 operated as Trans World Airlines Flight 800 from John F. Kennedy Airport, New York, to Charles DeGaulle Airport, Paris, France, impacted into the Atlantic Ocean at approximately 40'39'52" N, 72°37'46" W near East Moriches, New York. The crew of 18 and the 212 passengers received fatal injuries and the airplane was destroyed. The scheduled air carrier flight was operated under Title 14, Code of Federal Regulations (CFR) Part 121. Visual meteorological conditions prevailed and an instrument flight rules (IFR) flight plan was filed.

D. DETAILS OF THE INVESTIGATION

1.0 Wreckage Recovery and Impact Information

The wreckage recovery began immediately after the accident with several vessels picking up pieces that were floating on the surface of the water. Subsequently, the wreckage that sank was remotely surveyed using a variety of techniques, principally side scan sonar and laser line scanning. The aircraft was flying on a true course of approximately 075°. The wreckage was distributed along a true course of approximately 060 in three major dispersals, all of which lay predominantly to the south of the aircraft's ground track. The wreckage was generally distributed as far west as 72°40' 48"W, as far east as 72°35' 38"W, as far north 40°40' 12"N, and as far south as 40° 37' 42"N.

The three major dispersals of wreckage resulted in three specific debris fields being identified. The westernmost was originally known as area 3, because it was the last of the three to be located. Subsequently, this became the red zone. Its comers were:

40° 39' 21.72"N,	072° 40' 43.26"W
40° 37' 16.68"N,	072° 40' 47.59"W
40° 37' 16.58"N,	072° 37' 20.03"W
40° 38' 57.02"N,	072° 37' 16.47"W
40° 38' 57.73"N	072° 37' 51.32"W
40° 39' 18.20"N	072° 37' 50.60"W

The corresponding distance dimensions of this area are approximately 2.65 nautical miles along the east west axis by 2.1 nautical miles along the north south axis. However the northeast comer of the rectangle overlaps Area 1 by approximately .375 nm square and is part of Area 1 (Green). (See Appendix A, Section A 1 for detail of wreckage recovery areas and wreckage distribution).

Within the Red zone, a second zone was identified. This much smaller zone was originally known as Area 2, and subsequently was identified as the yellow zone because it is where the bulk of section 41 and the forward two thirds of section 42 (comprising most of the fuselage forward of the wing) were found. The corners of this zone are:

40° 38’ 54.12”N	072° 38’ 10.35”W
40° 39’ 11.75”N	072° 38’ 09.72”W
40° 39’ 12.29”N	072° 38’ 36.48”W
40° 38’ 54.66”N	072° 38’ 37.1O”W

The dimensions are 0.34 nautical mile along the east/west axis by 0.28 nautical mile along the north south axis. The entire zone lies within the northeast corner of the red zone.

The third debris field is the easternmost field. This was originally known as Area 1 and subsequently became the Green zone. The corners are:

40° 40’ 02.73”N	072° 35’ 37.98”W
40°38’ 55.03”N	072°35’ 40.41”W
40° 38’ 57.73”N	072° 37’ 51 .32”W
40°40’ 05.44”N	072° 37’ 48.92”W

Its dimensions are 1.65 nautical miles along the east/west axis and 1.125 nautical miles along the north/south axis.

In addition, an area 2.7 nautical miles in radius, centered at 40° 38’ 54”N, 072° 40’ 23”W, was defined. The portions of this area that did not already lie in either the Red, Yellow or Green zone were designated the Orange zone. The center of this zone corresponds to the last secondary radar return from the aircraft.

The database created to track recovered parts is known as the TAGS database. A series of metal tags were issued to be attached to the recovered parts as durable identification tags. The metal tags were colored one of six possible colors.

Red	Recovered from Area 3, or the “red” area
Yellow	Recovered from Area 2, or the “yellow” area
Green	Recovered from Area 1, or the “green” area
Blue	Recovered floating on the surface
Orange	Recovered from areas other than Areas 1, 2 or 3 during the trawling operation.
White	Area of recovery cannot be determined

Each tag number is preceded by a letter designator. Prior to September 5, 1996, the letter designators were A (Red area), B (Yellow area) and C (Green area). Following

the hurricane which passed the area, it was considered prudent to change these letter prefixes, since it was considered that some wreckage may have shifted position due to the hurricane. Thus, after September 4, 1996, the following letters were used: X (Red area), Y (Yellow area) and Z (green area).

The letter D designates a piece that could not be associated with a specific wreckage field (White tag). The letter E designates a floating piece (Blue tag).

After the recovery ships concluded diving operations, a trawling program was executed, using scallop boats with bottom dragging equipment to dredge the sea floor for parts. Any part recovered in this effort was given a colored tag appropriate to the area in which it was recovered; however, all pieces recovered in this effort were designated with unique letter prefixes. The letters T or M indicate a part recovered during the trawling prior to January 1, 1997. The letter N and P indicates a part recovered during the trawling after December 31, 1996.

Following the letter designator, a number between 1 and 9999 was applied. These number series reflect the following information:

1-1999	Issued on the recovery ships prior to the hurricane
2000-2999	Issued at the Calverton hangar prior to the trawling operation. Exception: Z2551 -Z2650. These 100 tags were issued on the warping tug.
3000-3999	Issued on the recovery ships following the hurricane of September 4, 1996.
4000-4999	Issued at the Calverton hangar to wreckage recovered during the trawling operation.
5000-5999	Issued by SUPSALV personnel at Moriches
6000-6999	Issued on the trawlers working Area 1 (Green)
7000-7999	Issued on the trawlers working Area 3 (Red) Note: During the trawling operation, the Area 2 (Yellow) was not considered distinct from Area 3 (Red). Note: Tag numbers T7064-T7084 were issued onboard the Tradition while she was operating in Area 1 (Green). However, the tags were colored red in error. For accuracy, refer FBI lot #.

8000-8999	Issued on the trawlers working the eastern half of the Orange zone, and the area of the Orange zone that lies both within and north of the AT&T cable safety zone.
9000-9999	Issued by the trawlers working the western half of the Orange zone.

Due to the enormous number of pieces recovered, not all parts were tagged. Large parts were tagged consistently, as were smaller parts that were identifiable and considered significant. However, a considerable volume of unidentifiable material was not tagged.

The FBI Evidence Response Team executed an evidence identification program, which placed a recovery date and recovery shipment ("lot") number on each piece that entered the hangar at Calverton, Long Island, New York. This program marked every piece that was recovered. Often, the lot number can be traced to a single debris field. Occasionally, lots were mixed (red and/or green and/or yellow), thus making it impossible to associate a specific debris field with a particular lot number.

A detail description of wreckage recovery operation and wreckage distribution is documented in Data Study Report and is prepared by the Data Management Team. This team was responsible for proper placement of tags on recovered wreckage.

The wreckage was laid out on the hangar floor with a lengthwise grid corresponding to the manufacturer's longitudinal fuselage station designation system. Other areas of the hangar floor were laid out with the appropriate grids for placing parts such as wing structure, wing center section with associated structure, and body fairings. Parts that were identified were placed in the appropriate position on the floor. Parts that could not be associated with a specific airplane position, but could be classified by type of structure, were placed in one of several piles. Each of these piles was unique to a particular type of structure and to a specific debris field. Parts that could not be associated with a type of structure, but could be associated with a debris field, were placed in a miscellaneous pile that was associated with the specific debris field.

Parts that were associated with the powerplants were transported to the hangar that housed the powerplants for documentation by the PowerPlant Group. Likewise, parts that were associated with the cabin interior were transported to another hangar where the cabin interior was documented and mocked up.

Major structures, substructures and significant components were documented. The documentation was subdivided into 12 subgroups. These are: left fuselage, right fuselage, left wing, right wing, horizontal stabilizer, left elevator, right elevator, vertical stabilizer, rudder, wing center section, floor beams and landing gears. Each structure, prior to documentation, was assigned a documentation number. The following nomenclature was

established for the documentation numbers:

LF-XX	Left fuselage
RF-xx	Right fuselage
LW-XX	Left main wing
RW-XX	Right main wing
H-XX	Horizontal stabilizer (both sides)
LE-XX	Left elevator
RE-XX	Right elevator
V-XX	Vertical stabilizer
R-XX	Rudder
CW-lxx	Wing Center Section upper skin
CW-2XX	Wing Center Section lower skin
CW-3XX	Wing Center Section right side-of-body rib
CW-4XX	Wing Center Section left side-of-body rib
CW-5XX	Wing Center Section front spar
CW-6XX	Wing Center Section spanwise beam no. 3
CW-7XX	Wing Center Section spanwise beam no. 2
CW-8XX	Wing Center Section mid spar
CW-9XX	Wing Center Section spanwise beam no. 1
CW-l0XX	Wing Center Section rear spar
CW-11XX	Wing Center Section butt line zero rib
FBM-XX	Floor beam
LG-XX	Landing gear

The Structures Group documented the airplane structural pieces individually and catalogued them in the Structures Group Factual Note Books. These books are comprised of textual documentation, drawings and photographs organized by part documentation number. For example, the piece of wing center section structure upper skin designated CW-101 has its textual documentation, sketches and photographs all located under the divider labeled “CW- 101” in Book 1 of the Wing Center Section Structure. This divider is followed by the divider labeled “C W- 102” with its documentation, and so forth. The books are comprised of the left fuselage, right fuselage, left wing, right wing, wing center section structure, empennage, landing gear and engine pylons.

From this basic documentation, a Factual Summary Report was drafted for each of the basic structures (fuselage, wings, empennage, wing center section, landing gears, engine struts). These reports comprise general descriptions of the significant features found in each of these basic structures. More detail will be found in the Structures Group Factual Note Books as described above.

The documentation for each individual piece, as well as each of the factual summaries, were reviewed and accepted by the accredited representatives of each party to the investigation.

This report and the factual summary reports include references to fire damage. The detailed description of all fire-related damage is included in the Fire and Explosions Group Chairman's Factual Report. Documentation of fire damage in the Structures Group Factual Summaries refers to any evidence of fire-related damage, including thermal discoloration and the presence of soot as well as thermal damage to metal structure.

This report also includes detail sketches of structure and wreckage recovery/distribution plots which is cataloged in Appendix A of this report. Appendix A has several sections, as indicated below:

Section	**Detail of Sketches**
A1	Wreckage Recovery and Wreckage Distribution
A2	Fuselage
A3	Wing
A4	Center Wing Section (Also called as Wing Center Section)
A5	Empennage
A6	Landing Gear and Landing Gear Assemblies
A7	Engine Struts (Also called as Engine Pylons)

The Structures Group was also responsible for the documentation of fractures on important parts of the airplane wreckage. This documentation was done with the help of a Metallurgical Group and is cataloged in a separate book titled "Metallurgical Factual Notes". A Sequencing Group was formed to document the aircraft breakup sequence. This documentation is titled Metallurgy/Structures Sequencing Group Notes. In addition to the above mentioned reports, there are various Metallurgical Group laboratory reports which were generated by the Metallurgical Group to document structure.

2.0 **Fuselage**

The fuselage of the airplane was severely fragmented and recovered predominantly from the three debris fields. (Some parts were recovered outside these established debris fields during the trawling operation.) The Red debris field contained fuselage pieces from an area just forward of the center wing tank. Generally, these pieces were from the circumference of the fuselage between fuselage station (STA) 840 and 1000; all of the pieces in this area of the fuselage have not been accounted for. The Yellow debris field contained fuselage sections generally forward of STA 840. The Green debris field contained fuselage sections generally aft of STA 1000. Some of the fuselage pieces from each of the above areas have not been identified.

Following are the acronyms used in this report:

STA	Body Station
CWS	Center Wing Section

s-	Stringer
KBB	Keel Beam Box
LBL/RBL	Left/Right Buttock Line

2.1 Forward Fuselage

2.1.1 Section 41 and Forward End of Section 42

The forward section of the fuselage from STA 90 to approximately STA 840, comprising Section 41 and part of Section 42, was found in the Yellow debris field. The fuselage skin and supporting structure extending below the right side passenger windows at stringer 22R (S-22R) and the left side cargo floor (S-37L) broke into small sections and suffered severe damage from inboard-acting compression/crushing forces. (See Appendix A Section A2 for detail sketches).

The fuselage section above S-22R and S-37L, including the crown, broke into larger sections. The upper crown stringers (lR, O, lL, 2L, and 2AL) near STA 840 exhibit evidence of pure tension fracture. There was no evidence of pre-existing corrosion or cracking found on this section of the fuselage. There was no evidence of foreign object impact to the cockpit windows.

There was no evidence of in-flight or post-crash fire damage to pieces of this section of the fuselage structure. There are numerous locations of dark/blackened discoloration near the electrical standoffs and ground terminals (LF 1 lB and RF4).

2.1.2 Aft Portion of Section 42

The section of fuselage from approximately STA 840 to STA 1000, comprising the aft portion of Section 42, broke into several large pieces. Most of these pieces were found in the Red debris field. A section of the fuselage skin aft of the R2 door (RF 1), just below the window belt, and above the cargo floor exhibiteda “peeling” deformation. The aft, upper corner of the skin is curled outboard, down, and forward (with respect to the fuselage axis system), and then continues its curl wrapping around into itself. There is similar peeling darnage to the corresponding region of skin on the left side of the fuselage (LF5), such that a nearly symmetrical condition has resulted.

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Between STA 860 and 960, the main deck window belts and the fuselage skin above the window belts on both sides (S-6 to S-23) exhibited longitudinal compression buckling deformation (LF12A, LF12B, LF38, LF59, LF74, LF85, RF20, RF21, and RF35). This condition is most severe immediately above the window belts and diminishes going up the fuselage. There is also evidence of stringer compression failure along a diagonal line from approximately STA 1000/S-17L up to STA 1060/S-3L (LF38).

Longitudinal fractures through skin rivet lines were examined by the Structures group with assistance from an NTSB metallurgist for evidence of “net area tension” (direct circumferential tension, with crack initiation equally from both sides of the rivet holes). Several such areas were found on the lower right side skin (between LF6A and RF95, between LF6A and RF32, and between RF 32 and RF 1). The stringers at the forward end lower lobe of LF6A (Red zone) exhibit evidence of tension fractures. (See Metallurgy/Structure Sequencing Group Report for further details.)

Major longitudinal fractures in the Green zone pieces (aft of the Red zone) were also examined for evidence of net area tension. No indications of net area tension failures were found. All examined fractures which progressed along rivet lines were “running” fractures, generally in the aft direction.

Crack directions in the skin were determined wherever possible and generally indicate that forward, right fuselage cracking proceeded upward toward the crown in the Red zone. The direction of the cracking continued across the crown, and then down the left side to the window belt and L2 passenger door area. On the left side, fracture surfaces indicate that lower cracking appears to have progressed upward from the belly and proceeded to a juncture with the right side cracks at the left side window belt/L2 door.

Several pieces of fuselage belly skin were totally separated from the frame shear ties and stringers (LF24A & LF95). The left side of the fuselage forward of the wing center tank front spar (STA 1000 to STA 900) and below the passenger floor (S-39L to 28L) fractured into several small pieces and were recovered from the Green debris field. The skin in this area exhibited heavy damage (deformation/curling) and was totally separated from the frame shear ties and the majority of the stringers. One piece (LF63) exhibits evidence of outward bulging, or “pillowing”, of the skin.

The fuselage belly skin in Section 42 receives longitudinal load/support through 1) the keel beam structure, and 2) the underwing drag splice fittings, which are located at the intersection of the wing lower surface with the fuselage skin, (approximately right and left S-38).

2.2 Center Fuselage (Section 44)

.2.2.1 Keel Beam Structure

Keel Beam Box (KBB) structure is located below the center wing tank and extends from approximately STA 985 (lower end of the center wing front spar) to STA 1480 and from left buttock line (LBL) 9.0 to right buttock line (RBL) 9.0. The KBB broke into several large sections. The forward section of the KBB from the wing front spar aft to STA 1152 remains in one piece and exhibits slight soot damage. This section was found in the Red debris area. The KBB structure from STA 1152 to STA 1480 broke

into several pieces and exhibits heavy sooting. These pieces were found in the Green debris area.

STA 1000 to 1152 Keel Beam Structural Damage (LF 14A)

The two vertical web attachments and lower keel chords at the front spar lower bulkhead were fractured (LF14A, LF55C, LF55D & LF55E). The lower chord fractures at the front spar exhibit evidence of bending in the vertical plane (crack initiating at the top of the chord's cross-section). All attachments of the KBB upper chord to the Center Wing Section (CWS) lower surface were fractured. Both right and left KBB vertical webs fractured along the stiffener at STA 1152. Both lower chords fractured at STA 1150. The cross-bracing members below the mid-spar bulkhead beam and spanwise beams #2 and #3 remained intact. Metallurgical examination of the chords fractured at STA 1150 revealed bending in a vertical plane (crack initiated at top of chords' cross-sections) with a river pattern emanating from the upper surface of the fracture, which is indicative of downward bending.

Bolts attaching the KBB upper chords to the CWT at the front spar, spanwise beam #3, spanwise beam #2, and the mid-spar bulkhead remained with the KBB upper chords. The tops of these bolts, except for those at the front spar, exhibited evidence of bending in the aft direction. The mid-spar attachment bolts have the most dramatic deformation and were bent aft approximately 60 degrees from the vertical.

STA 1152 to 1338 Keel Beam Box Structural Damage (LF14B and LF 14C)

The KBB left vertical web is missing aft of STA 1255. The left lower keel chord is fractured at STA 1230 and STA 1252 and the aft end of the vertical web is deflected outboard. Inner KBB cross-bracing members at spanwise beam #l (STA 1171.5) and at the rear spar were severely damaged. Inner KBB cross-bracing intercostals/support structure at STA 1265 and at 1330 separated from the left hand keel structure. The lower horizontal web between keel chords aft of STA 1144 was missing.

STA 1338 to 1480 Keel Box Structural Damage (LF14D)

The right side aft KBB structure (LF14D) from STA 1363 to STA 1466 was comprised of the lower keel chord segment, vertical web segment, upper chord segment, the STA 1416 A-frame outer chord and web segment, and remnants of the main body landing gear drag strut and jury strut support fitting. The lower keel chord segment was cracked through at STA 1400. The portion of the landing gear support fitting that attaches to the landing gear drag strut is missing. There was no evidence of sooting on LF 14D. A small section of the keel chord segments and fittings remained attached to the right and left main body landing gear drag/jury struts (RF43).

Keel Beam Box Soot Profile

The outer surfaces of the keel box from the front spar to STA 1152 exhibited evidence of dirt and/or light sooting. The right side outer surface, both fore and aft of STA 1129, exhibited evidence of sooting in an upward/forward direction and aft direction. There was no evidence of sooting on the inner surfaces of the keel box from the front spar to STA 1152. The right and left side outer surface of the keel box from STA 1152 to STA 1265 exhibit 'heavy sooting and diminishes aft of STA 1265. (See Fire and Explosion Group Factual Report for further details).

2.2.2 **Underwing Drag Splice Fitting Damage**

Both underwing drag splice fitting attachments were fractured. Each one broke through the wing ("male") part at the aft-most splice bolt location just forward of the front spar intersection. A section of the right side splice remained with the fuselage section RF95 and a section of the left side splice remained with fuselage section LF51. The mating section of these fittings remained with wing center tank lower skin sections CW216 and CW221 .

2.2.3 **Bulkhead Frames**

The bulkhead frames are utilized in Section 44 to redistribute loads between the wing, fuselage, and the landing gear assemblies. These bulkhead frames are located at STAS 1000, 1140, 1241, 1350, and 1480. All bulkhead frames were broken into numerous parts of varying lengths and sizes.

The bulkhead frame at STA 1000 (front spar) separated from the CWT adjacent to the front spar attachment points. A section of the front spar web and backup structure (LF38 and RF37) remained attached to the bulkhead frame. An edge of the spar web just inboard of the right side bulkhead fitting inner leg exhibited evidence of metal abrasion and aftward bending (approximately 90 degrees); witness marks are evident at the bend location. There are several witness marks on the wing box internal stiffener aft chord flange which exhibit similar metal abrasion with slight bending damage. The front spar web immediately above the 90 degree bend exhibits inter-fastener, forward bending, and. the spar web is pulled away from the wing internal stiffener. This occurs along a vertical length of approximately 15 inches. The STA 1000 bulkhead frame failed in the region between S-1 lR and S- 10R where upper and lower frames splice together. The lower section of the bulkhead frame (RF37) exhibited significant sooting, but there was no evidence of sooting on the upper section (RF34).

The STA 1140 (mid spar) bulkhead frame broke away from the top of the wing box on the left hand side (CW1 08) but remained attached to the large fuselage/wing box section on the right side (RFl 7).

The STA 1241 (rear spar) bulkhead frame broke apart on the left side just above the CWT upper spar chord (C WI 008 & CW1 O 16). The lower attachment fitting (picklefork) remained attached to various pieces of rear spar web and backup structure. The two attachment prongs of the picklefork had broken apart from each other. The right side picklefork remained attached to the large fuselage/CWT section (RF 17). The" forward/aft-oriented flanges of the prongs were buckled out of plane and the rear spar web segment was pushed aft at its lower edge, taking it out of the spar web plane.

The STA 1350 bulkhead supports the wing landing gear support beams and separates the wing landing gear wheelwell from the body landing gear wheel well. This bulkhead broke into several large pieces.

A large segment of the STA 1350 lower bulkhead is attached to the RF38 part. The RF38 part is comprised of the following: 1) The lower portion of the STA 1350 bulkhead, encompassing the right side landing gear beam to LBL 75 (This part has a major fracture at RBL 75, from WL 186 down to the lower chord.); 2) The right side fuselage skin structure from STA 1350 to 1480, from S-23R down to the longeron; 3) A segment of the BL O web 20 inches forward and aft of the STA 1350 stiffened web; and 4) A portion of the KBB upper surface from 8 inches forward to 8 inches aft of STA 1350.

The left hand landing gear beam separated from the STA 1350 bulkhead and fractured into several large segments.

The upper section of the STA 1350 bulkhead frame contained a black smear, consistent with tire rubber, on the inboard chord from S- 15L up to a fracture point at S-6L (LF39A). The bulkhead frame above the fracture point shows no evidence of the substance (LF69). A piece of tire rubber were found lodged under the stringer flange at S-9L.

The lower portion of the STA 1480 bulkhead frame broke into multiple pieces (LF45A&RF31), with no body landing gear trunnion support fittings attached. Most of the left side support fittings remained with the corresponding landing gear (LG 3). All of the right side support fittings and a portion of the bulkhead web remained attached to the right body landing gear (RF 119).

2.2.4 **Fuselage Skins (Section 44)**

The Section 44 fuselage structure is located above the wing and extends aft over the wheel wells. The forward edge of theLF38 and RF37 segments from the Green debris field form the boundary with the structure recovered from the Red debris field. The RF37 segment exhibits a small local outboard curling deformation at the forwardmost edge that mates with "curled" segment RF 1 (red zone). The LF38 segment also shows similar deformation as RF37 and exhibits diagonal wrinkles.

The frame inner chords in the area over CWS, segments RF 17, RF37, and LF38, show signs of compression damage near STR 24. The side of body intercostal running between the frames and the BL 98.5 longitudinal floor beam that remain attached to the segments RFl 7 and LF38 are deformed in such a manner that the inboard end is displaced upward.

2.3 Aft Fuselage (Section 46)

The fuselage section 46 structure, from STA 1480 to STA 2360, was recovered from the Green debris area. The upper fuselage structure broke into relatively large sections and the lower fuselage structure, including the aft main and bulk cargo doors, fragmented into smaller pieces. The longitudinal boundaries between these two levels of damage were approximately located along the window belt on the right side and stringers 28L-31 L on the left side. The upper fuselage structure sections generally had pieces of frames either totally or partially detached from skin and stringers (RF9A). Skin panels bounded by the area of S-22L to S-28L, between STA 1800 and STA 2100, are practically void of all frames and stringers. The lower fuselage structure sections (LF41) typically exhibited inboard bulging of the skin bays (i.e., the area between adjacent stringers and adj scent frames) similar to the forward lower lobe of Section 42. This area is generally devoid of frame segments below the main deck floor. These segments often included stringers broken in two or damaged at each frame station, with this characteristic being most common toward the aft of Section 46 (LF52).

The aft pressure bulkhead at STA 2360 broke into several small and large sections, which were recovered from the Green debris area. The lower portion of the bulkhead exhibits evidence of compression damage sustained in the radial direction as demonstrated by web and stiffener buckling (LF 10 F). Side segments of the pressure bulkhead exhibited evidence of compression damage in a circumferential direction, with web and stiffeners accordioned together (LF 10A & LF 10E). The majority of the bulkhead pieces separated from the “Y” shaped ring chord, which attaches the bulkhead to the fuselage, along the bulkhead’s inner row of web splice fasteners. The bulkhead’s lower region (LF 10F), however, remained attached to the ring chord, with failure occurring in the monocoque along a circumferential line passing through the forward fasteners of the stringer splice fittings.

2.4 Aft Fuselage (Section 48)

The Section 48 fuselage skin (aft of STA 2360) broke into large sections and the majority of these segments have intact stringers and some frames. The majority of these pieces do not show substantial compression type damage (RF27, RFl15 & RFl06).

3.0 Wing

The wings were fractured into numerous pieces. A small percentage of fuselage and wing center wing tank were still attached to the wing structure when recovered. The wing landing gears and engines (covered in other summaries) were not connected to the recovered wing debris. The vast majority of the left wing pieces and all of the right wing pieces were found in the Green debris field. Some small pieces of the left wing were found in the Red and Orange areas. The right wing sustained fire and soot darnage on the exterior of the upper and lower skin surfaces The left wing lower surface showed sooting and some fire darnage, generally between engines #1 and #2. The sooting and fire damage are covered extensively in the Fire and Explosion Group's Report. Most pieces of the leading and trailing edge flaps, ailerons, and spoilers were found in the Green debris area however, some pieces were found floating and were not associated with a debris field. (See Appendix A Section A3 for detail sketches).

3.1 Right Wing

The right wing had separated into two major sections. The inboard section includes approximately 20 inches of center wing tank, a portion of fuselage and the wing outboard to approximately wing station (WS) 1224. The outboard wing section measured approximately 29 feet and comprised the wing from approximately WS 1242 (at front spar and leading edge) to the wing tip. The wing structure between the inboard and outboard sections (WS 1224 to WS 1482) had broken into several pieces. Fire and soot darnage was observed mainly on the inboard wing section, with some limited fire and soot damage on the other pieces.

3.1.1 **Inboard Right Wing Section**

The upper and lower wing skins of the inboard wing section remained together on the ocean bottom. Underwater video of the entire piece as originally found on the ocean bottom showed the wing resting on its lower skin. As a safety precaution to personnel, the wing skins were cut and split at several locations after recovery from the ocean. Both upper skin (RW8) and lower skin (RW3) show an inboard-to-outboard wave shape along the entire span (lower skin has a more pronounced wave). The inboard ends of the upper and lower skins remained attached to portions of the center wing upper and lower skins; the inboard end of the upper skin was also attached to a portion of the fuselage (BS 1140 to BS 1340, RF17). The attached piece of center wing upper skin (CW104) exhibited upward bending. The attached piece of center wing lower skin (CW201) and the inboard right wing lower skin exhibited pronounced upward bending. Most of the stringers remained attached to the lower skin and were bent in an "S" shape spanwise taking the shape of the darnaged wing skin. Sooting is prevalent along the length of the external surfaces and the upper skin inside the vent stringer area.

The front spar from WS 1196 to the SOB had mainly separated from the upper and lower skins and was found in many pieces of various sizes. Only a 15-foot section outboard

of engine #3 and a 10-foot section inboard of engine #4 remained attached to the lower skin (RW3).

The majority of the mid spar of the right wing was missing from its attachments on the upper and lower skin and was found in small pieces.

A large section of the rear spar between the #3 and #4 engines remained attached to the lower skin and exhibited fire and impact damage (RW3). A 10-foot section of the rear spar between WS 440 and WS 560 (including the main landing gear "H" fitting) remained attached to the upper skin (RW8), and a 6-foot section of the rear spar between WS 582 and WS 650 remained attached to the lower wing skin (RW3).

There is evidence of fire and soot damage to the upper wing skin and associated stringers immediately outboard of engine #4 exhibiting heavy soot and some fire darnage (RW8). The inner surface of the upper skin inboard of the #4 engine exhibited soot in vent stringer passages but no fire darnage (reference to Fire and Explosion Group notes).

3.1.2 Outboard Right Wing Section

The outboard wing section, which measures from approximately WS 1242 (at front spar and leading edge) to the wing tip, was found floating on the ocean surface (RWl and RW4). The exact recovery location of this section is unknown. However, due to the recovery of the right hand HF antenna (RW22) (which was originally attached to the wing tip) in the Green debris area it was determined that this section was also recovered from the Green area. The front spar lower chord fracture surface at WS 1243 exhibited tensile failure characteristics and the upper chord fracture surface at WS 1242 exhibited compression failure characteristics. The front spar web was deformed aft from the fracture areas to WS 1280. There was no evidence of any soot damage, fire damage, or pre-existing cracking or corrosion on this wing structure.

3.1.3 Right Wing Between Inboard and Outboard Sections

The wing structure between the inboard and outboard sections had broken into several pieces. The upper wing skin measured from WS 1224 (just outboard of #4 engine) to WS 1280 and had broken into numerous sections (RWl 1, RW19, RW20, RW21, and RW37). Layout of these pieces showed upward bending, and also panel segments (RWl 1, RW20, and RW21) were buckled in compression and bent upwards at the inboard and outboard ends. No evidence of fire damage or soot accumulation was observed on these pieces, although some stringers that remained attached to the upper skin (RW8) in this area exhibited heavy sooting and some fire damage. A separated rib at WS 1252 .(RW24) exhibited heavy fire damage, and an adjacent 10 foot piece (RW25), which includes segments of the WS 1280 rib, a vent stringer, and a Z-stringer, was less sooted and burned. The lower wing skin piece (RW1O) from WS 1224 to WS 1482 shows a general spanwise curl downwards and is twisted over its length. Most of the stringers show a buckling of the

free flange. There was no evidence of any pre-existing cracking or corrosion on these pieces of wing skin.

3.2 **Left Wing**

The left wing was more severely fragmented and the lower panel had a more pronounced spanwise curl than the right wing. Generally, the left wing had separated into upper skin pieces and lower skin pieces; only one piece outboard of the #1 engine (LW5&6) had upper and lower skins still attached. Most of the upper skin was found, but in small fragments. Almost all of the lower skin was recovered and comprised of larger pieces.

The left wing outboard of about WS 1230 (outboard of engine #1) broke into eight larger pieces and numerous smaller pieces. Layout of these pieces showed upward bending outboard of about WS 1230 (LW8 & LW42) and possible downward bending outboard of .WS 1360 (LW5&6, LW44). Both upper and lower wing skin panels between WS 1230 and WS 1360 showed upward curling at the inboard end (upper panel LW42 and lower panel LW8). The front spar fracture at WS 1242 exhibited buckling damage to the upper chord and web. The lower wing panel outboard of WS 1360 shows downward curling at the inboard end and one large crease near WS 1423 (LW44), with both ends of the local panel bent downward about the crease. Buckled stringer upper chords (free flanges) were observed on panels LW8, LW44, and LW5.

The upper and lower skin (LW5&6) remained attached to the front spar between WS 1440 to WS 1548. The inboard end of the lower skin (LW5) at WS 1440 exhibited evidence of downward bending, and towards the outboard end, (WS 1548), the front spar is fractured and the skin panel end is bent down over the outboard 10 inches (LW5).

There is evidence of sooting on the lower skin inner surface at WS 1230 near the front spar (LW9). A section of the front spar that remained attached to the lower skin and the corresponding fracture surfaces of the spar and the skin also exhibited evidence of sooting. The adjacent section of the lower skin (LW8), which is bent upward at the inboard end, exhibited no evidence of sooting. These localized sooting areas show soot on the inside surface only but not on the inside surface of the mating pieces. In some cases, the soot extends to and onto the fracture face, but is not evident on the mating piece or its fracture face.

The lower wing skin inboard of approximately WS 1230 was broken into numerous large pieces. These pieces exhibit a pronounced downward bending condition. There is evidence of exterior sooting on the lower skin pieces from WS 400 to WS 1200. There is no evidence of sooting on the inner surface of the wing lower skin, except on some curled pieces near the rear spar and #1 engine (LW40 and LW41) and in a small (2 square foot) area near the front spar just outboard of the #1 engine (LW9 outboard end).

The upper wing skin from the SOB out to approximately WS 1200 broke into many small segments. These segments vary from a few square inches to a maximum of twenty square feet. Most of the larger pieces are curled upward from an inboard to outboard direction (opposite the direction of the lower skin). There is no evidence of any soot or fire damage to the inner or outer surface of these upper wing skin segments.

The left wing SOB pickle fork fitting (CW1015) and a portion of the terminal fitting attached to small pieces of the rear spar (CW1 024) exhibit bending in the aft direction. The fracture features are consistent with bending in the aft direction at both the middle of the pickle fork and the middle of the terminal fitting. The areas around the left wing rear spar upper surface and the left SOB where the pickle-fork fitting is attached suffered severe damage.

The majority of the stringers (including vent stringers) from the SOB to WS 1220 had separated from the upper and lower skin. These stringers were bent and curled in various directions and were pulled from the skin.

The entire mid spar had separated from the wing upper and lower skin. Some of the mid spar was found in small segments.

Small segments of rear spar remained attached to the lower skin at WS 1230(3 feet, on LW8) and WS 1485 (5 feet, on LW5). The remaining rear spar was missing or found in small pieces.

Five segments of the front spar remained attached to the lower skin from #1 engine outboard to WS 1280 (LW8 and LW9). Another segment of the front spar remained attached to the lower skin from WS 1400 To WS 1530 (LW5). A third piece of front spar remained attached to a piece of upper wing skin from WS 1280 to WS 1400 (LW1 O). The remaining front spar was missing or found in small segments.

3.3 **Wing Control Surfaces**

Most pieces of the leading and trailing edge flaps, ailerons, and spoilers were found in the Green debris area; however, some pieces were found floating and were not associated with a debris field. These pieces showed general impact damage. Many portions of the trailing edge flaps, ailerons, and spoilers and some portions of the leading edge flaps showed fire and/or soot damage,

3.3.1 Flaps

Most of the right-hand wing trailing edge flaps were identified/recovered The inboard flaps separated into large pieces and show little or no fire or soot damage. There is evidence of severe impact damage, including damage to the honeycomb and associated skin (RW16, RW34, RW33). The outboard flaps separated into numerous smaller pieces and

show heavy fire damage. The entire outboard flap sections were recovered and identified, except for a very small area (RW26 to RW32).

The left side inboard fore flap broke in three distinct pieces (LW25). All of these pieces suffered fire damage and severe impact damage. A large section of the inboard mid flap remained attached to the flap track assembly (LW21). The mid flap box suffered severe impact damage. The upper and lower surfaces of the mid flap section also exhibited evidence of fire darnage. Only a very small area of the left-hand outboard flaps were identified (a few square feet), and these small pieces were not individually documented.

3.3.2 **Flap Tracks**

All 8 trailing edge main flap support tracks were recovered (Trailing edge flap support tracks are numbered, left wing outboard (#1) to right wing outboard (#8)). Left wing flap tracks #1, #2, and #3 exhibited impact darnage, with fractures occurring mostly in the forward sections. Flap track assemblies #1 (LW23), #2 (LW43), #3 (LW22) separated from the aircraft primary structure from their forward and aft mounts as individual pieces. All these pieces exhibited evidence of sooting. Flap track #4 (LW21) remained with a section of the mid flap and exhibited sooting. The right wing flap track assemblies, #5 (RW13), #6 (RW23), #7 (RW14), and #8 (RW1 8), separated from the aircraft primary structure from their forward and aft mounts as individual pieces. Very small portions of the mid flap remained attached to flap track #7 and #8. There is no evidence of fire damage to any of these flap track structures.

3.3.3 **Ailerons**

All four ailerons were found in pieces, with the largest varying in length from 4 to 8 feet. The left outboard aileron broke in several pieces (LW47, LW34, LW33, LW32) and exhibited evidence of fire damage on some pieces. The inboard aileron broke into two sections near the middle (LW35 and LW36) and had been severely damaged by impact and fire The right outboard aileron broke into three distinct pieces (RWl 5). These three sections suffered minor impact darnage on the skin surfaces but no fire darnage. The inboard aileron actuator and associated mounting bracket (RW17) were recovered from the Green area. The actuator and a small section of aileron structure separated from the remaining aileron structure, No evidence of fire damage was documented.

3.3.4 Spoilers

All four inboard spoilers and their actuators were recovered. The inboard-most on each wing (LW24 and RW35) show fire and soot darnage, and the outboard-most on each wing show impact tearing and fracture darnage.

The outboard spoilers on the right wing were still attached to the rear spar (RW3) but were badly burned. The outboard spoilers on the left wing were not identified.

3.3.5 Leading Edge Structure and Fixed Trailing Edge Structure

Fixed trailing edge structure, including supports for panels, spoilers, ailerons, etc., have not been specifically assembled or cataloged. There are many tom, fractured, and/ or burned pieces in the hangar.

Some leading edge structure, both flaps and fixed components, were assembled (mostly for the left wing), but no significant patterns were observed. Numerous pieces of the right wing leading edge were identified but were not assembled or cataloged. Some pieces have significant fire damage.

4.0 Center Wing Section

List of acronyms and abbreviations:

C w s	Center Wing Section (Also called as Wing Center Section)
STA	Body Station
WL	Water Line
LBL/RBL	Left or Right Butt Line
BBL	Body Butt Line (also BL)
FS	Front Spar
MS	Mid Spar
RS	Rear Spar
LSOB/RSOB	Side-Of-Body (R or L), same as BBL 127.5
AFT	Aft direction
SWB	SpanWise Beam
RHMLHS	Right/Left Hand Side

Notes:
1. See the attached figure for Center Wing Section configuration
2. Detailed descriptions of all the damage to the CWS are presented in the various sections of the C WS documentation.
3. For fire and sooting damage, see Fire and Explosion Group documentation.
4. For metallurgical information, see Metallurgical Group documentation.
5. For detail sketches, see Appendix A Section A4 of this report.

4.1 General Description

The center wing section (CWS) is a multi-cell box which connects the right and left wings through the fuselage It is comprised of five cells formed by the Front Spar (FS), SpanWise Beam (SWB3), SWB2, the Mid Spar (MS), SWB1, and the Rear Spar (RS). The CWS extends chordwise from the front spar at approximately STA 1000 to the RS at approximately STA 1238 and spanwise between the left side-of-body (LSOB) rib at LBL 127.5 to the right side-of-body (RSOB) rib at RBL 127.5. The SOB ribs separate the CWS

from the outboard wings. The MS from both of the wings connect through the CWS at fuselage STA 1140. There are three spanwise beams (SWB) in the CWS which extend from the left to right SOB ribs. SWB3 at STA 1042 is aft of the FS. SWB2 at STA 1096 is aft of SWB3 and forward of the MS. SWB1 at STA 1180 is aft of the MS and fwd of the RS. The CWS has upper and lower skin panels which are connected to all the spars and beams thus forming a closed box structure. The whole CWS box section is an airfoil shape and has the same contour as that of the outboard wings at the side of body. On N93 119 (a 747-100) the center fuel tank is bounded by the RS on the back, a LSOB and RSOB on each side, and SWB3 on the front. The area between SWB3 and FS is a dry bay.

Typical design and construction of the FS, MS, and SWB'S consist of "I" shaped vertical stiffeners which are connected to a web with rivets. The upper and lower ends of the vertical stiffeners attach to shear ties which are bolted to the upper and lower skin of the CWS. There are tension fittings at locations where the spanwise beams intersect the longitudinal floor beams and where the spanwise beams intersect the keel beam. The upper and lower edges of the webs attach to "L" or "J" shaped chords. The horizontal flanges of these chords are fastened to the upper or lower skins of the CWS.

The RS and SOB ribs have "Z" shaped stiffeners which are connected to a web with rivets or bolts. The upper and lower skins have "Z" shaped stringers connected to the skins with rivets or bolts.

The MS, RS, SWB's, SOB ribs, and the upper skin panel utilize 7075 aluminum alloy. The FS web and the lower skin panel utilize 2024 aluminum alloy.

The CWS fractured into multiple pieces with the majority of the pieces recovered from the green debris area. Approximately 75% of the FS, 60% of the SWB3, and the manufacturing access door from the SWB2 were found in the Red debris area. Most major components of the CWS have been over 90°/0 identified with the exception of the region of LSOB rib. The right side of the CWS both interior and exterior is generally much more heavily sooted than the left side. There are also localized area within the CWS which exhibit significant fire and heat damage. There is a wide range in size of the recovered pieces however some of the smaller fragments are associated with the LSOB region. The LSOB rib web was fractured into numerous small pieces with an average size of approximately six to eight square inches. These pieces are curled and bowed and a general direction of deformation could not be determined. The web of the RSOB aft of MS exhibit evidence of outboard bowing. The entire upper skin from LSOB to RSOB exhibits a multiple wave deformation pattern. The lower skin panel exhibited no general deformation pattern.

Examination of the damage to the upper part of SWB3 and FS of the CWS revealed that the SWB3 fractured at the connection to the upper skin and rotated forward about the connection to the lower skin impacting the aft surface of the FS. The FS fractured at the connection to the upper skin panel and rotated forward into the forward cargo compartment.

4.2 **Front Spar (FS)**

The front spar fractured into four large sections, covering most of the span, along with several smaller pieces. Outboard of LBL 100 and RBL65, small FS segments were found in the green debris area. The middle of the FS consisting of 75% of the total spar was found in the Red debris area. The section comprising the center of the FS web (BLO) had two vertical ruptures, and the edges of the ruptures were curled forward at various locations. The FS web has punctures and small holes at various locations. The skin around the edge of the holes is either curled forward or aft.

Most of the FS stiffeners, which are attached to the aft side of the web, had impact damage on the aft flanges. The damage is approximately 11”-14” below the upper shear ties with the flanges generally crushed forward at these locations. This darnage is consistent across the aft side of the FS web at various spanwise locations. Black impact marks were observed on the aft side of the spar web just to the right of BBL O and on the aft flange of the adjacent stiffener at RBL 11.07. The impact marks are spaced approximately 1.5” apart and each mark is oriented approximately 45 degrees down (from the left horizontal). The impact marks on the web were located approximately 45 degrees forward and down to the left from the impact marks on the stiffener.

The left side bottom corner of the FS fractured into numerous small pieces. These pieces were curled 180 degrees forward and outboard. All of the pieces from this area were recovered from the Green debris area. The web segment from just inboard of the left SOB to LBL 76.00 (CW504) had no significant scrapes or gouge marks, and was relatively straight.

There was evidence of small fatigue cracks in the FS shear ties along the lower chord at several locations. Details of this documentation are included in the Metallurgical Group notes.

There was evidence of small (less than l”) “spike-tooth” fractures[1] at four locations on the web of the FS: RBL 5, RBL 6.8, RBL 30.99, and RBL 37.99. Details of this documentation are included in the Metallurgical Group notes.

4.3 **Spanwise Beam #3 (SWB3)**

The SWB3 fractured into five large sections, extending across most of the span, and several smaller sections. The right outboard segment from RSOB to RBL 78 was found in the Green debris area and exhibited fire damage. Three vertical stiffeners remained attached to the web, but were separated from the upper shear ties. The area of SWB3 near RBL 95 was laterally crushed and badly mangled, and the stiffeners were bent slighly forward. The

[1] Fractures exhibiting a spike tooth characteristic are indicative of a very rapid strain rate produced by a high energy event.

web/stiffener structure is bowed forward from the bottom. Spike-toothed fractures were observed at seven locations on SWB3 between RSOB and RBL 83.24.

The structure from inboard of RBL 57 to LBL 75.9 separated into three large sections and was found in the Red debris area. There was light to medium soot on these sections. In general, the vertical stiffeners remained attached to the web but the lower shear ties had separated from the lower skin. The web of the beam in this area was relatively straight.

The section outboard of LBL 75.9 to LSOB fractured in numerous small pieces. All of these pieces were found in the Green debris area and exhibited evidence of sooting. The web was curled 90 degrees forward at LBL 100.

The forward face of this beam constitutes the aft face of the dry bay area of the CWS. All the heads of the rivets that are used to assemble the web to the stiffeners are coated with black sealant on the forward face. The spacing between the rivets is 1.5", in both vertical and horizontal directions. Most of the stiffeners exhibited impact damage and were fractured anywhere from O" to 12" below the upper skin.

4.4 Spanwise Beam #2 (SWB2)

The SWB2 fractured into four large and several smaller sections. All of the pieces were found in the Green debris area, except for one piece near the center (CW703) that was found in the Red area. The location of one piece (CW706) was unknown (white tag). The right outboard section from RBL 98.5 to the RSOB rib was heavily distorted and bent with multiple folds. The section from RBL 91.10 to RBL 25.2 (CW702) remained attached to the upper skin, and the web was fractured just under the upper chord from RBL 57 to the right outboard end. The lower edge of the web separated from the lower chord and the remaining fasteners in the web exhibited shear fractures. This piece exhibits spanwise compression damage (accordion shape) to the web and attached stiffeners. The outboard edge of this web section was generally curled aft. Spike-tooth fractures were evident in this section and the entire section was sooted with the exception of the lower edge of the web.

The manufacturing door with a small piece of web attached (CW703) was found in the Red debris area. The rivets that attached the door to SWB2 exhibited shear and/or tension failures. The door exhibited an S-shape deformation, with forward bending except at the lower left comer, which was bent aft and shows impact damage on lower edge. The deformed shape of the door did not match the shape of its surrounding structure. The door had three penetrations in the forward direction. Light soot, as opposed to heavy soot on the surround structure, was observed on the forward side of the door.

A section of lower chord and web from the right, inboard portion of SWB2 (CW704) was found in the Yellow debris area. The lower chord separated from the CWS lower skin and the fasteners attaching the chord to the skin failed in tension, except one

fastener just outboard of RBL 9 which exhibited aft bending. The inboard edge of the web (inboard of the stiffener at RBL 9) had numerous horizontal fractures and was curled tightly forward at several locations. The web just outboard of the stiffener and directly below the door (CW703) was bent 180 degrees aft. The web inboard and outboard of RBL 25 has multiple penetrations with very jagged features around the edge of the hole. Spike-tooth fractures were observed on portions of the web section.

Section CW705, which consists of web and stiffeners just left of BL 0.0 including a honeycomb access door, was recovered in the Green debris area. The stiffeners, web, and door exhibited forward bending. The access door was bowed forward and the middle of the door was missing, with the surrounding honeycomb shredded forward. Most of SWB2 left of the door is missing.

4.5 Mid Spar

The mid spar fractured into one large section (RBL 85 to LBL 49) and several smaller pieces from the right and left outboard area (RSOB to RBL 68 and LBL 49 to LBL 110, respectively). One of the right outboard pieces was recovered from the Yellow debris area (CW805), but the rest were found in the Green debris area. Reconstruction of these pieces revealed no distinct deformation pattern of the web or stiffeners, but did contain evidence of sooting. The lower end of the stiffener web flange on C W805 was bent inboard and aft.

The large section of the mid spar extended from RBL 85 to LBL 49 and from the lower chord to the upper chord (CW801), with 12 stiffeners remaining attached. This section of the mid spar exhibits evidence of fire damage and sooting. The lower chord is bent aft 45 degrees at LBL 17.27 and is fractured at RBL 34.00. The upper chord remains attached to the upper skin panel from RBL 17.00 to LBL 17.00. The left side of the mid spar was bent aft approximately 12” at LBL 44.65. The lower, left half of the mid spar bent diagonally aft from LBL 17.00 at the upper chord to RBL 34.00 at the lower chord. The extreme left lower comer at LBL 44.65 bent aft 90 degrees. The right access door was bowed slightly forward. A portion of the left access door aft skin was burned and bent aft. The forward skin of this door is missing.

The mid spar section from LBL 49 to LBL 110 fractured into numerous pieces. The bulkhead web attach flange of the stiffeners remained attached to the web for most of the pieces and the web is bowed aft both inboard and outboard about LBL 75. One section of the mid spar between LBL 60-90 exhibited an “S” shape deformation inboard to outboard and was sooted.

4.6 Spanwise Beam #1 (SWB1)

The SWB 1 fractured into three large sections (on the left side) and numerous smaller sections. The smaller sections were located on the right side from RSOB to RBL

53.00 (CW903, CW909 to cW913) and were found in the Green debris area (except CW911, which has been tagged white).

CW909 included a 36-inch section of upper chord and the web between R13L 76 to RBL 40. Some of the fasteners common to the upper skin exhibited tension and/or shear failure. The free flange of the chord at the outboard end was bent up. The lower web edge at RBL 60 had a portion of the web bent forward, and exhibited spike-tooth fractures. Only the web flange of the LBL 49.6 stiffener remained and was bent forward. There was sooting on the skin flange and the web flange of the upper chord at the aft side and some sooting on the forward side of the web.

Two inboard lower web edges at RBL 67 (CW911) were curled aft. The upper portion exhibits a 4-inch long spike-tooth fracture along its lower edge.

The fasteners through the upper shear tie common to the upper skin on the SWB 1 section from BLO to RBL 53 remained attached and exhibited tensile failure.

The forward side of the access door remained intact and the aft face sheet was missing with very little damage to the honeycomb core.

The left side of SWB 1 fractured into three large sections, (CW901, 902, 907) and each of the sections had evidence of heavy sooting with local areas of fire damage. A large section (CW901) extending from the stiffener at LBL 57.51 to approximately BL O. This includes the upper chord, the web, one access door, stiffeners at LBL 11 through LBL 57.51, and stabilization straps. The upper 34" of the stiffeneratLBL57.51 is not attached to the web and shows a shear failure of the rivets common to the web on CW902. The rest of the stiffeners remained attached to the web. The majority of the stiffener free flanges remain attached except at LBL 11.00. The stiffeners did not exhibit any notable bending in the fore/aft direction. The access door remained attached to the adjacent vertical stiffeners and web. There is a hole in the honeycomb core and the core ribbon around the hole is shredded in the aft direction.

4.7 **Rear Spar (RS)**

The RS fractured into four large pieces (CW1OO1, CW1OO3, CW1OO4 and CW1006) and numerous smaller pieces. All were found in the Green debris area. Section CW1001 included the right hand rear spar terminal fitting (pickle fork fitting) and the rear spar web from upper to lower surface and from RSOB to RBL 85.00. CW1001 remained attached to a section of upper fuselage that was heavily burned. The pickle fork remained attached to the web but the free flange of the fork legs buckled/crippled, with the lower spar chord being displaced 12" to 16" aft of its original location. There was no soot on the forward side of the web and the aft side of the web was dirty, typical of its normal exposure to the dirt inside the wing landing gearwheel well.

The section inboard of the right pickle fork fractured into numerous smaller sections. Another section (CW101 O) consisted of a lower portion of the web and lower spar chord from RBL 10 to RBL 85. The skin flange of the lower spar chord and the attached lower skin panel was bent upwards at RBL 52 at approximately a 20 degree angle. The fasteners common to the spar chord, web, and missing stiffeners (at the lower chord) showed tension failures.

A section containing a portion of the web from LBL 11 to RBL 33 at the upper spar chord and LBL 19 to BL O at 10" above the lower chord suffered damage on the entire periphery of the web, with the edges bent both forward and aft. The lower portion of the web was bent forward approximately 180 degrees. The CWS scavenge pump is not attached to the spacer plate or the spare web. The mounting spacer plate for the CWS fuel scavenge pump remained in place on the aft side of the rear spar, but it had been deformed away from the spar web except at the 9-11 clock position. The three bolts that mount the spacer to the spar web were in place and the safety wires were still attached. There was a partially sooted outline of the pump housing on the spacer plate and a difference in soot levels on the forward side of the spar web where the pump is mounted as compared with the remainder of the web. There is only a very light soot deposit on the spar web where the spacer plate has been deformed from the web. The forward side of the lower portion of the web that is bent up 180 degrees has a location that shows impact damage to the web and to the fillet seals on the fastener heads. This section shows heavy soot and fire damage on not only the forward and aft surfaces but also on the web and stiffener fracture edges. It also shows marked difference of soot levels as compared with the adjacent segments. The stiffener to web interface at LBL 11 shows both sooted and unsooted regions on the interface where the stiffener is missing. The protruding portion of the fasteners that have failed also show soot accumulation.(See Fire and Explosion group notes for details of the sooting and fire damage). Two segments of the rear spar (CW1OO9) remained attached to stiffeners that remained attached to the keel beam box.

The left outboard end of the CWS rear spar consisted of small (CW1OO8, CW1015 and CW1 O 16) segments of the outboard leg of the left rear spar pickle fork fitting near the SOB, along with a portion of the left rear spar terminal fitting and the web adjacent to the fitting. The terminal fitting on CW- 1008 was fractured on the inboard side at approximately the inboard edge of the pickle fork. The fasteners common to the pickle fork and terminal fitting on CW1OO8 remained intact. The outboard aft flange of the pickle fork (CW1 015) was broken from CW1 008, consistent with a counter-clockwise rotation of CW1 015 (as viewed from above). The fracture was primarily in the fillet radius between the two portions of the fitting. The holes in the terminal fitting showed deformation downwards and inboard. Marks observed on the outboard side of the fail-safe strap on CW-1015 were coincident with the fastener locations on the adjacent outboard wing segment.

4.8 Upper Skin

The upper wing skin fractured into eight large sections and numerous smaller sections. All of these items were found in the Green debris area.

The right forward section (CW101), included part of the upper skin panel, stringers, and floor beams, extends from the RSOB to LBL 30, and from S-22 to the FS The underside of the skin panel contains most of the stringers from S-22 to S-33 and includes the skin flange of the FS upper chord. The panel is bowed up approximately 12" at RBL 57.5 and the stringer at S-31, 32, and 33 are buckled and broken at RBL 57.5. The tension fittings at SWB3 remain intact on the lower side of the skin panel as well as the portion that remains attached to the floor beam on the upper side. (See sketch in CW602 for complete definition of remaining tension fittings on the lower surface). The left outboard end of the panel at LBL 30.00 has a very jagged fracture and has portions curled upwards as much as 45 degrees. The stringer splice fittings at RBL 127.5 (which attaches to the RSOB) at S-30 to S-33 remain attached to the stringers. The fastener holes common to the double plus chord are elongated inboard and outboard at the lower surface of the holes with a slight elongation on the upper surface of the holes. There are small metal fragments embedded in the sealant on the lower surface of this panel. (See Metallurgy Group Report for further description of these fragments.) There is no evidence of pre-existing cracks or corrosion on this panel. Some sooting is evident on the lower surface of the panel.

The left forward section of the upper skin fractured into smaller sections. The inboard fracture edge at LBL 30 is jagged and curls upwards at 45 degrees. The outboard edge bends down at a 45 degree angle on a 15" radius and has jagged edges. The forward portion of the upper skin is buckled in an "S" shape as viewed from the front (view looking aft).

The mid section of the skin fractured into three large sections on the right and several smaller sections on the left. The right portion of the upper skin (C W1 04) remains attached to RW-7 which was cut for reconstruction. The stringers at S-24 through S-26 have no skin panel above them and approximately 25" of each stringer is bent upwards at 90 degrees. There is evidence of heavy sooting in this area.

The fasteners remaining in the double plus chord free flange and the stringer end splice fittings at S-31 through S-33,(CW104) exhibit shear failures in both inboard and upward directions. This section exhibits sooting and fire damage.

A large piece of mid upper skin extending from the rear spar to S-18 with its inboard edge at RBL 80 (CW1 05) is still attached to the upper section of the fuselage (RF17) that is heavily burned. The fracture line running approximately at RBL 80 is extremely jagged, and the end of the panel and the attached stringers are bent upwards at 45 degrees starting at RBL 100. The upper chords of the stub beams that attach to the RBL 98 floor beam are buckled and bent aft. The inboard end of the stringers S-10 through S-13 match the general deflection of the upper skin panel. The tension fittings at RBL 98 at both SWB 1 and the MS remain attached on the upper and lower surfaces of the skin. A portion

of both the MS and SWB 1 remain attached to the upper skin near the RSOB. The portion of SWB 1 is bent aft at its inboard end and the portion of MS is bent slightly forward at its inboard end. There is heavy sooting and fire damage on the upper surface and some soot on the lower surface.

A very large section of the upper skin mid section (CW1 02) includes of portion of skin panel, stringers, and floor beams that extend from RBL 78 to LBL 45, and from SWB 1 to S-22. It also has a large section of MS (CW801) and SWB2 (CW702) still attached. The skin panel has multiple smaller fractures and bends of varying radii in several directions, but is generally bowed up at the inboard and outboard ends. The fracture edge at LBL 45 has a local curl down. The forward edge of the panel at SWB2 is bent upwards at 35 degrees and there is a fracture in the panel aft of SWB2. Just forward of SWB2, there is a 3 inch x 1 inch vertical puncture in the skin, At LBL 20 just aft of the MS, there is a semi-circular 6 inch x 8 inch delamination on the skin lower surface that is bent down approximately 4 inches from the inner surface of the panel. It remains attached on the inboard edge. Small metal particles were found imbedded in the sealant in the lower surface of this panel. There is evidence of heavy fire damage.

The aft side of the upper skin fractured into two large pieces and several smaller pieces at the aft left corner. The right aft side (CW1 03) extends from LBL 5 to RBL 100 and from RS to SWB 1. The upper surface of this panel is burned. Only the skin flange of the upper rear spar chord remains attached. The forward edge of the fracture goes through the fastener line at SWB 1.

The inboard edge of the panel is bent upwards 10 degrees starting approximately at RBL 8. The left side (CW1 35) extends forward from the rear spar to SWB1, and from LBL 98.6 inboard to about LBL 5. The panel is bowed up approximately 12 inches about a fore-aft axis located at its mid span.

A significant portion of the left side of the upper skin, inboard of the LSOB, fractured into numerous small sections.

4.9 Lower Skin

The lower skin fractured into six large sections and several smaller sections. All these sections were found in the Green debris area.

The entire right side of the lower skin (CW201) extends from S-1 to S-23 was cut from the lower right hand wing skin (RW3) for reconstruction of the CWS. The inboard edge of the skin from rear spar to S-5 is curled down and the stringers are separated from the panel from S-1 to S-4. At S-5 the stringer matches the periphery of the panel and remains attached. Between S-6 and S-8 there is a portion of the panel that is fractured at RBL 110 and the outboard edge is bent downwards whereas the inboard edge between S-7 and S-8 is bent upwards. The skin between S-11 and S-13 extending inboard, has a very

jagged fracture pattern and is bent both upwards and downwards at multiple locations. The skin portion between S-1 5 and S-23 exhibits general upward bending with multiple smaller curvatures both upwards and downwards. Just forward of S-21, the skin is fractured from RBL 127 to RBL 100 and the outboard edge of the skin forward of this fracture is bent down. The skin splice stringer flanges remain attached to the skin panel with some fiisteners, and the majority of the remaining fractured fasteners indicate tension failures. The majority of the fastener holes on the skin do not exhibit elongation except at SWB 1, S-1 7 and S-22, where there is some elongation of holes fore and aft On the forward right outboard side of this section, there is evidence of pillowing of the skin between the stringers in an upward direction. There is evidence of fire darnage and soot accumulation. (See the Fire and Explosion Group notes for further detail).

The forward side of the lower skin separated in two large and three smaller sections (RH comer). The forward left side (CW221) is a large section of skin panel with stringers that extends from the LSOB to RBL 33 and from S-15 to the FS. Using the area at BLO as a reference, the panel bends down 15 degrees at LBL 43 going outboard and bends up at a 10 degree angle at LBL 72. The depth of the bend is 7 inches at the FS and about 12 inches at SWB 3. There are small fatigue cracks on the aft side of the FS shear ties at LBL 84 and LBL 92. There is also a small fatigue crack at the fillet radius of the FS chord near the Iongeron splice at LBL 80. (For documentation of the fatigue cracks, see Metallurgical Group report.) The upper tension fitting on the upper surface of the skin panel at the Iongeron splice is fractured through the tension bolt hole and is deformed at the forward end. The lower tension fitting attached to the lower surface of the panel is intact, but the hole for the horizontal tension bolt is elongated vertically. The underwing longeron fitting exhibits a tension failure at the aft bolt hole with some bending to the left. There is some soot on the inner and outer surfaces of the skin panel.

The mid section of the lower skin fractured into one large section (CW207) and numerous smaller sections located on the right and left sides. The panel (CW207) is bent down at the center (approximately LBL 50), and there is a fracture near the forward edge that extends from the inboard edge aft of SWB2 to LBL 16. This fracture produced a section of skin panel that is bent sharply up at the aft edge and down at the forward edge. There are only a few rivets remaining in the skin panel and they exhibit shear failures. Only a portion of the skin flange of the keel beam attach chord remains attached with some fasteners, and the remaining fractured fasteners exhibit tension failures. The fastener hole that is common to the keel beam tension fitting at SWB2 exhibits elongation in the forward direction on the lower surface. The upper and lower surfaces are sooted.

The aft section of the lower skin (aft of MS) fractured in two large sections and various smaller sections at the aft left comer. A large section (CW205) is bent in “S” shape and is comprised of skin panel and stringers that extend from S-4 to the midspar (S-1 O) and from the LSOB to approximately RBL 92. The S-7 and S-8 stringers remain attached to this section at the LSOB paddle fittings and are bent and twisted in several directions. There is a puncture in the skin panel 6 inches forward of SWB1 at LBL 37 with the surrounding skin

bent down. The right end of this section has the general shape of an upward deflected dome that is as high as 14 inches in relation to the adjacent structure. The dome is centered about RBL 57.5 between S-8 and S-9. The sections around this area including CW232, CW231, and CW201 exhibit this same general domed shape. A spike-tooth fracture occurred at RBL 39 just forward of S-9. There is soot on the upper and lower surfaces of the panel.

Another large section (CW202) extends from RBL 98 to LBL 69 and from approximately S-1 to S-5 and has only a small section of S-5 skin flange remaining attached. The panel is bent in an inboard/outboard direction with the RH and LH sides both bent downward from BLO. The right side is bent down approximately 10 degrees and the left side is bent down starting at 10 degrees and gradually increasing to about 45 degrees. The few rivets remaining in the skin panel exhibit shear in an inboard and outboard direction, but the fasteners at RBL 57.5 at S-2, 3, and 4 are bent aft ranging from 45 to 60 degrees. On the right outboard side of this section, there is evidence of pillowing of the skin between the stringers in an upward direction. The keel beam attachment stiffeners at RBL & LBL 9.0 have pulled away from the lower skin and the fasteners exhibit evidence of tension failures. There is evidence of sooting on the lower surface of the skin.

4.10 Right Side-Of-Body Rib (RSOB)

The RSOB fractured into six larger sections and numerous smaller sections. The majority of the pieces were recovered from the Green debris area. Recovery locations of some of the sections are unknown and are designated with white tags. These pieces were assembled on the floor to determine the mode of failure. In general, the RSOB exhibited evidence of outboard bulging in the forward and mid sections.

The RSOB forward section is comprised of CW308, CW309, CW31O, CW3 17, and CW335 which exhibit evidence of outboard bowing when assembled. In addition, other forward smaller sections (CW3 13,CW314 and CW3 17) also exhibited evidence of bowing. One piece (CW3 14) is bowed inboard at the center with rivets remaining in the fastener holes that exhibit shear failures. CW313 and CW317 are heavily bowed outboard at their centers. CW313 has a few fasteners remaining in the holes that exhibit combinations of tension and shear failures. CW317 has rivets that exhibit tension failures and some that exhibit shear failures. The webs of all three sections are sooted on the inboard side and clean on the outboard side.

The mid section of the RSOB is made up of CW303, CW304, and CW323. The segment CW303 extends forward 36 inches from the MS location up to SWB2, and is 40 inches high. The upper edge of this segment remains attached to the double plus chord vertical flange located between CW301 and C W302. The web is generally flat except for the lower fracture edge which has a slight inboard curvature (an indication of outboard bowing). There are soot deposits on this part. The section CW304 previously had a Yellow tag and was changed to a White tag. The aft fracture edge of this part mates with CW323. A small section CW323 has forward and aft sides bowed inboard 2 inches about SWB 1

stiffener. When assembled with other pieces this section exhibited evidence of outboard bowing.

The aft section of the RSOB includes CW305, CW306, CW3 11, and CW3 12. The section CW305 contains the first two stiffeners aft of SWB 1 and exhibits a significant outboard bulge of heavy web and stiffeners. The fracture lines are clean. The remaining sections of the aft RSOB are relatively flat.

4.11 Left Side-Of-Body Rib (LSOB)

The web of the LSOB fractured into numerous small sections. The average size of the web pieces are approximately six to eight square inches. About 70 percent of the web remains either unrecovered or unidentified. Recovered pieces are curled and bowed, and a general direction of the bow could not be determined.

The lower chord of the LSOB rib fractured into numerous smaller lengths ranging from 2 inches to about 20 inches. These chord sections have “U” or “S” shapes. The lower chord pieces were assembled to determine the mode of failure. The assembly exhibited a general inboard outboard wave shape running forward and aft. The MS stiffener fractured into two sections (CW407A and C W407B). The lower section (CW407B) remained attached to the lower chord and is bowed outboard. The upper mid spar section (CW407A) is bent 90 degrees outboard at the lower end. There is no evidence of any fire damage or soot accumulation on the pieces of the LSOB rib.

4.12 Body Butt Line 0.00 Rib (BBL O)

The BBL O rib extends from the MS to SWB 1 (forward bay), and from SWB 1 to the RS (aft bay) along the centerline of the center wing tank. The aft bay section fractured into one large and several smaller pieces. The forward bay fractured into several pieces. All the pieces were found in the Green debris area.

A large section (CW1103) of the BBL O rib, extends from SWB1 aft to CW1102 (about 8 inches forward of RS) and from the upper skin panel down to a few inches above the lower skin panel. This section is bowed about 5 inches to the left at its center. The connection at the forward end where the rib attaches to the SWB 1 is bent to the right. All the vertical stiffeners remain attached to the panel, except some have outer flanges missing, There is evidence of sooting on both sides of the part.

The BBL O rib between MS to SWB 1 fractured in several smaller sections. A segment (CW1 101) of the BBL O rib from the MS extending aft 20 inches has a general “S” shape along the forward vertical edge. The bow in the upper end is centered about 11 inches from the top and bows to the right. The bottom has jagged fractures which are bent up and to the left. A small section (CW1105) mates toCW-1101 and is fractured just above the lower rib chord on the lower side. The fractures around the periphery of the part do not follow

fastener lines. There is a flap of web on the front of the part about 4 inches wide that is folded over to the right. CW-1 106 extends from the SWB 1 forward about 10 inches and from the upper chord down 52 inches, and is generally flat. The top 6 inches of the forward edge is folded down to the left. All the sections between MS and SWB 1 exhibit evidence of sooting.

5.0 **Empennage**

The horizontal and vertical stabilizers, elevators, and rudders fractured into numerous sections. These sections were found either floating or in the Green debris area.

Following are the acronyms used in this report:

Stab STA	Stabilizer Station
LBL/RBL	Left/Right Buttock Line
WL	Water Line
LHWRHS	Left/Right Side

5.1 Horizontal Stabilizer

The horizontal stabilizer fractured in six large sections and numerous smaller sections. These sections were assembled on the hangar floor to document the darnage and determine the mode of failure All the fracture surfaces were examined and there was no evidence of any pre-existing cracking or corrosion. The fracture surfaces of the left (at approximately Stab STA 210) and right (at approx. Stab STA 335) sides of the horizontal stabilizer exhibit evidence of compression and tension type fractures on the upper and lower skins, respectively. The leading edge was severely damaged. Some of the items found in the horizontal stabilizer are sections of seat track, a stator blade from turbine section, and glitter. (See Appendix A Section A5 for details of sketches),

5.1.1 **Right Horizontal Stabilizer**

The right horizontal stabilizer inboard section remained attached to the horizontal stabilizer center torque box (Hl). The outboard fracture of this section was located near Stabilizer Station (Stab STA) 360, approximately. The upper skin in this area exhibited evidence of slight buckling. A few of the lower skin stiffeners are bent in the forward direction. The rear spar remained attached to this section from the torque box to Stab STA 285 and exhibited bending in aft direction at STA 285. The leading edge from the inboard end to Stab STA 235 was damaged. The remaining leading edge ribs inboard of Stab STA 153 are bent inboard and the leading edge ribs between Stab STA 196 to 235 approximately are bent outboard. About 50 inches of the leading edge outboard of Stabilizer STA 235 remained attached.

The outboard section of the right Horizontal Stabilizer (H3), from Stab STA310 to the tip, remained in one section. The rear spar at the inboard end was bent aft. The front spar just inboard of the Stab STA 385 was bent forward. The leading edge from the tip to Stab STA 385 remained attached to this section. The leading edge exhibited numerous dents along its length and was crushed aft at the inboard end for about 8 inches in length. The outboard-most 12 inches of the leading edge was crushed aft and outboard. This area exhibited black rub marks on the leading edge skin in the lateral direction. An engine stator blade from turbine section penetrated the upper honeycomb surface near the outboard trailing edge.

The leading edge section (H6) between HI and H3 is comprised of leading edge skin and ribs. The ribs fractured and separated from the front spar. In general, the aft ends of the rib webs were bent slightly outboard. The bull nose skin was dented along its length.

The inboard nose section (H7) of the right Horizontal Stabilizer included the leading edge to the auxiliary spar. The lower skin surface was torn and bent down and forward.

A section of the structure outboard of H7 exhibited evidence of red paint transfer marks on the upper skin (H8); only the remnants of the shattered logo light window remain in the window frame

5.1.2 Center Torque Box

The torque box remained intact but had a few puncture holes on the upper skin. The rear spar of the torque box suffered no impact damage. When viewed from the rear, the RHS and the LHS stabilizer hinge fitting lugs were rotated approximately 10 and 5 degrees counterclockwise, respectively. The front spar web of the torque box between LBL 14.5 and RBL 14.5 was tom and bent forward. Along the front spar, the RHS of the torque box is displaced slightly upwards relative to the LHS.

The Jack screw extends above the Jack screw fitting by ten threads and is fractured at the bottom of the fitting. There was minor deformation observed on the support frames of the screw jack, the LHS upper support has an 1/8 inch gap between support frames

5.1.3 Left Horizontal Stabilizer

The left Horizontal Stabilizer fractured into three large sections and numerous smaller sections. These sections were found in the Green debris area.

The aft portion of the left Horizontal Stabilizer from the torque box left side to Stab STA 187 (approx.) remained attached to the torque box. This section comprised the upper and lower skins and a 3-foot section of the rear spar. The upper and lower skins were bent up. The stringers from the lower skin were bent up and aft. The upper skin stringers remained attached to the skin and were bent up. The rear spar section remained attached to

the torque box and was bent aft. There are local soot deposits on the exterior and interior surfaces of the upper stringers and skin.

A large inboard section of the leading edge of the horizontal stabilizer (H5) included a section of the front spar from Stab STA 143.60 to leading edge STA 233 (approximately). The front spar web was bent slightly aft at the lower corner near the root; no deformation of the outboard end was observed. Just forward of the front spar, outboard end, the upper skin was torn and two pieces were bent up approximately 60 and 180 degrees, respectively.

Another section of inboard left Horizontal Stabilizer (H4) comprised an area from Stab STA 198 to 271 and included a 5-foot section of rear spar, a small section of the upper skin, and a section of left elevator (LEIA). The inboard portion of the rear spar section, from Stab STA 235 to 37 inches inboard, was bent aft approximately 20 degrees from the spar reference line. The outboard portion of the rear spar, from Stab STA 260 to 11 inches outboard, was curled aft approximately 45 degrees.

The outboard portion of the left Horizontal Stabilizer comprised the area from Stab STA 230 to the stabilizer tip. The upper and lower skins remained attached to the front and rear spar on (H2A). The lower skin and the stringers at the inboard end are bent up at Stab STA 230 to 285. The corresponding upper stringers near the rear spar are bent forwards. The rear spar remained intact from the tip to Stab STA 275. The front spar remained intact from the tip to Stab STA 347 and exhibit slight aft bending at the bottom of the spar web. The leading edge remained attached to the front spar from Stab STA 372 to stabilizer tip. The outboard and inboard ends of the leading edge upper surface from Stab STA 372 to 390 and from STA 460 to tip were torn in numerous locations and directions. The leading edge bull nose was crushed aft from STA 525 to 560 and the inboard end exhibited evidence of witness marks in the lateral direction. There were numerous punctures on the upper skin surface.

5.2 Elevators

In general, all the elevators separated from the horizontal stabilizer at the hinges, while the hinges themselves remained attached to the stabilizer structure. The only place where the elevators remained attached to the stabilizer were at locations common to the actuator fittings (LE1A, LE2B, and H1 -right inboard actuator). On the LE2B segment, the elevator was severely deformed. It remains in the upward direction relative to the stabilizer. At the hinge locations, the elevators leading edge upper skin was deformed up and aft, while the lower skin remained intact, except for LE1 A.

On both the left and right outboard elevators inboard of Elevator STA 356, the counterbalance weight structure is deformed or missing. Predominately, this structure is bent in the upwards direction. At these same locations the stabilizer lower panels between the hinge line and the stabilizer rear spar are missing. Outboard of Elevator STA 356 the

counter balance weight structure is bent upwards and the stabilizer panels between the hinge line and the rear spar remain with the stabilizer.

5.2.1 Right Elevator

The right, outboard elevator fractured into four large sections and two smaller sections. All of these sections were found floating. The outboard section (RE2F) exhibited evidence of fire darnage and soot on the upper skin outboard end. The RE2E part exhibited evidence of slight fire darnage and soot.

Only one section of the right inboard elevator (REl) was recovered and identified. This section is the inboard portion and exhibits evidence of fire damage on the honeycomb structure.

5.2.2 Left Elevator

The left outboard elevator fractured into three main sections and one small section. Two of these sections were found floating in the ocean, the third was attached to part H2A. On the LHS elevators identified there was only minor sooting and no evidence of fire damage.

Only two large pieces of the left inboard elevator were identified/recovered. There is little evidence of soot or fire damage. One large section (LEIA) remained attached to the left horizontal stabilizer section (H4) and was found in the Green debris area. The other section was found floating.

5.3 Vertical Stabilizer

The vertical stabilizer forward of the front spar to the leading edge fractured into two large sections (upper and lower) and several smaller pieces in between. The upper section comprised the area from Fin STA 370 to Fin STA 582.65 and from the leading edge to the front spar (Vi). The front spar chords were fractured near Fin STA 370 and exhibited no lateral deformation. Some of the ribs extending aft from the front spar exhibited downward bending. The front spar web is torn and pushed forward below Fin STA 560 and aft above Fin STA 560. There is no evidence of damage to the leading edge except at Fin STA 370 and 570, where the leading edge skin was torn and bent.

The lower forward section (V2) comprised the area from Fin Waterline (WL) 2.92 to Fin STA 220 and from the leading edge to the front spar. The right side of the front spar cap was bent slightly outboard at WL 2.92. There are two locations on the LHS skin along two Fin Station ribs where the panels are bowed outboard. The leading edge is crushed aft at numerous locations. A 14-inch leading edge section near fin STA 220 was crushed downward. About half of the front spar web was tom from the left and right spar chords and pushed forward.

The vertical stabilizer structure between the front and rear spars fractured into numerous sections. The right body fittings from the rear spar to stringer 9 of the vertical fin, separated with the right skin and stringers remaining attached (V9). The right skin was bent outboard at the upper ends. Remnants of the body bulkheads were still attached below the body fittings and were bent aft. Vertical skin panel V8, which mates with V9, was relatively flat except for slight bending outboard of the upper 10 inches of the panel. The left body fitting for the vertical fin separated, with the left skin and stringers remaining (V6). The left skin and stringer panel (V5), which mates with V6, is relatively flat. The V4 part consists of the upper vertical fin left skin panel and stringers between the front and rear spars from Fin STA 370 to 520. The lower panels (V5, V6, V8, and V9) exhibit an outward deformation at the lower fractured end, relative to the vertical fin surface.

5.4 Rudder

Four upper rudder segments and one lower rudder segment were identified. All were found in the Green debris **area** or floating.

Segment R1 comprised the upper rudder from Rudder STA 332 to the top and from the leading edge to the trailing edge. The outer skins had some punctures and minor surface abrasions. The leading edge seal shroud below the hinge exhibited impact damage.

Segment R2 comprised the upper rudder from Rudder STA 257 to 332.437 and from the leading edge to the trailing edge. The hinge fitting had minor impact damage and the hinge bolt remained attached to the hinge fitting. The outer skins had some minor punctures and surface abrasions and the right outer skin had a diagonal tear approximately 3 inches wide by 24 inches long. The leading edge seal shroud exhibited impact damage.

Segment R3 comprised the upper rudder from Rudder STA 147.722 to 207.615 and from the leading edge to the trailing edge. The front spar had numerous areas of cracking and impact related damage. The leading edge seal shroud had a large amount of impact damage. The hinge fitting had negligible damage with the pivot bolt remaining. The outer skins are cracked.

Segment R4 comprised a portion of the lower rudder from Rudder STA 82.792 to 107.757 and approximately 82 inches forward of the trailing edge. Portions of ribs at Rudder STA 82.792 and 95.275 remained attached. The outer skins exhibited cracking, punctures, and minor surface abrasions, and a portion of the left skin was missing.

Segment R5 comprised the upper rudder from rudder STA 182.651 to 232.579 and from leading edge to trailing edge. The rudder actuator assembly and the vertical stabilizer attach fittings remained attached to the front spar. The upper and lower rudder hinge fittings remained attached. The upper vertical stabilizer hinge fitting failed approximately four inches from the pivot, and the lower vertical stabilizer hinge fitting right half remained

attached to the rudder but not to the vertical stabilizer. Outer skin panels have cracking, punctures, and minor surface abrasions.

6.0 Landing Gear and Landing Gear Door Assemblies

6.1 General Description

The nose gear separated from the fuselage structure and was found in the Yellow debris area. Three out of four nose landing gear doors were found in the Red debris area and one was found in the Yellow debris area. All the main landing gear and main gear doors were found in the Green debris area. The nose gear suffered the least amount of impact damage as compared to the wing gears and body gears. All of the tires were recovered and documented in the System Group Notes. Refer to Fire and Explosion Group Notes for soot documentation. (See Appendix A Section A6 for detail sketches.)

6.2 Landing Gear Assemblies

6.2.1 **Nose Gear Assembly**

The nose gear assembly (LG1) separated from the fuselage and suffered impact damage. The outer cylinder, inner cylinder, axle, retract linkage, and trunnion fittings remained intact. The trunnion fittings separated from the fuselage structure and an eight foot-section of bulkhead at STA 340 remains attached to the retract fitting. The right tire, wheel, and outer hub separated from the nose gear assembly. Some portions of hydraulic lines remained attached.

6.2.2 Left Wing Gear Assembly

The left wing gear assembly (LG2) separated from the rear spar and the STA 1350 landing gear beam. The outer cylinder, inner cylinder, and truck remained intact. The gear assembly had separated from the trunnion fittings. Some hydraulic lines and wiring remained attached. The downlock bungee was fractured and separated from the gear assembly. The inboard jury strut link fractured and separated from the side strut and the outboard jury strut. The outboard jury strut link remained attached to the outer cylinder. Three of the four brake rods were fractured. The aft outboard axle fractured 8.5 inches “from the gear beam centerline. The retract stabilizing arms were bent and the aft stabilizing arm outboard section had separated from the gear assembly. The aft outboard tire, inner hub, outer hub, brake assembly, and outer portion of the axle had separated from the gear assembly. The forward outboard tire suffered impact darnage and exhibited several cuts. The forward inboard tire, inner hub, outer hub, and outer two-thirds of brake pads and rotors had separated from the gear assembly. The inboard aft tire, inner hub, outer hub, and brake assembly had separated from the gear assembly.

6.2.3 Left Body Gear Assembly

Left body gear assembly (LG3), outer cylinder separated from the inner cylinder and the axle beam fractured into two segments. The outer cylinder remained attached to the trunnion fittings which separated from the STA 1480 bulkhead. The jury strut had separated from lower drag link. The outer cylinder gland nut had separated and the piston had separated from the outer cylinder. The axle beam and connecting rods were fractured and many hydraulic lines remained attached. The retract piston pulled the aircraft structure attach fitting out of the aircraft structure. Both inboard tires, inner hubs, outer hubs, and brake assembly had separated from the gear assembly. The forward outboard tire, inner hub, outer hub, and brake pads had separated from the gear assembly. The aft outboard outer hub fractured and the tire separated from the gear assembly.

6.2.4 Right Body Gear Assembly

Right body gear assembly (LG4), outer cylinder separated from the inner cylinder and the axle beam fractured into two segments. The outer cylinder remained attached to the trunnion fittings. The trunnion fittings tore from the STA 1480 bulkhead. The outer cylinder to lower drag strut was fractured. The upper drag strut, jury strut, and a portion of the lower drag strut remained attached to the fuselage fitting which had separated from the fuselage. The outer cylinder gland nut was not attached. The outer cylinder suffered impact damage and was cracked vertically in the thread area. The axle beam and connecting rods were fractured. The retract piston was not attached to the gear assembly. Both outboard tires and the aft inboard tire were not attached. The outer hubs were fractured allowing tires to depart the gear assembly.

6.2.5 Right Wing Gear Assembly

The right wing gear assembly (LG5) separated from the rear spar and the STA 1350 landing gear beam. The outer cylinder, inner cylinder, and truck remained intact. The gear assembly had separated from the trunnion fittings. Some hydraulic lines and wiring remained attached. The downlock bungee was fractured. The jury strut had separated from the outer cylinder, but remained attached to the downlock actuator. The jury strut fractured at the side strut joint. All brake rods fractured. The' forward outboard axle fractured eighteen inches from gear beam centerline. The retract stabilizing arms were bent. The outboard tires, inner hubs, outer hubs, and brake pads had separated from the gear assembly. The forward inboard outer hub fractured and the tire separated from the gear assembly, The aft inboard tire exhibited cuts on the tread.

6.3 Landing Gear Door Assemblies

Except for the right body gear outboard aft door, all of the landing gear doors were accounted for. The documentation of the landing gear doors describes only the damage to the door structure.

6.3.1 **Nose Gear Doors (LG6)**

Left Forward Door

The forward and aft hinges were pulled out of the door structure and the middle hinge remained attached. The outer skin has smooth denting between ribs structure.

Left Aft Door

This door was severely damaged and crushed.

Right Forward Door

The forward door broke into two segments. The inner skin, outer skin, and internal structure fractured at approximately sixty-two inches aft of leading edge. The forward hinge separated from the door structure. The center and aft hinge locations have fuselage hinge fittings attached. The rod fractured one inch from the door fitting.

Right Aft Door

The outboard edge bent upward .75 inch at leading edge running aft to center hinge location.

6.3.2 **Left Wing Gear Doors (LG7)**

Outboard Door

The door structure suffered severe impact damage. The outboard door inboard hinge beam fractured at the aft edge of the center hinge. Portions of the inner skin, outer skin, and the honeycomb core suffered impact damage and a portion was missing. The outer skin has some punctures.

Inboard Door

Portions of inner skin, outer skin, and honeycomb core suffered impact damaged or was missing. The outer skin suffered impact damage and exhibited some punctures at various locations. Inboard and outboard doors remained attached to each other at the hinge locations.

6.3.3 Left Wing Gear Wheel Well Doors (LG7)

Inboard Door

The inboard door broke into two segments. The outer skin separated from the door structure. The aft three hinge locations have fuselage hinge fittings attached. The forward hinge location door hinge was fractured. At the second hinge location aft, the fuselage hinge was fractured. The aft inboard comer structure was crushed. The trailing edge has a dent and puncture. The rod fractured one inch from the door fitting.

Inboard Forward Door

The inner skin was cracked and suffered a dent. The outboard hinges were fractured. The inboard and outboard sections of the leading edge door seals had separated from the door and the rod had separated from the door.

Outboard Door

All hinges had fractured. The outboard outer skin segment had separated from the door. The rod fractured three inches from the door attach fitting. The aft inboard comer was crushed and the trailing edge midway outboard transition corner was crushed. The forward outboard comer was crushed and a portion had separated from the door. The inner skin surface suffered impact damage and had two holes. A section of seal assembly was found embedded in one hole, and a second hole was near the loose end of the seal assembly.

6.3.4 **Left Body Gear Doors (LG8)**

Outboard Forward Door

The outboard hinges had fractured and separated from the door. The inner skin suffered punctures, cracks, and flapping at various locations. The rod fractured at the door fitting.

Inboard Forward Door

The inboard frame had fractured at the hinge locations and the hinges had separated from the door assembly. The outboard hinges were fractured. The leading edge door seal had separated from the door assembly. The rod had separated from the door assembly. The forward transverse inner skin stiffener outboard twenty-four inches of vertical flange had separated from the door assembly.

Inboard Aft Door

The inboard aft door broke into two segments. Only the forward segment of the door could be identified and the aft segment of the door could not be identified. The forward segment separated approximately forty-one inches aft of leading the edge. The fuselage hinge was fractured at the forward hinge location. The second door hinge aft of the leading edge was fractured,

Outboard Aft Door

The outer skin was tom downward from the top approximately twelve inches and suffered various dents. The hinges were fractured. Approximately three inches of rod remained attached. The seal retainer was cracked and deflected.

6.3.5 Right Body Gear Doors (LG9)

Outboard Forward Door

The outboard hinges remained attached to the fuselage structure which is approximately 17 inches circumferentially x 130 inches fore-aft. The outer skin suffered dents and cracks. The rod was fractured 1.5 inches from the door fitting.

Inboard Forward Door

The outboard hinges were fractured. The inboard and outboard sections of the leading edge door seals and the support rod had separated from the door assembly.

Inboard Aft Door

The inboard aft door broke into two segments. There is evidence of numerous punctures, cracks, and skin flapping on the door structure. A fuselage fitting remained attached at the aft hinge location. The second hinge forward of the trailing edge was fractured. The third hinge forward of the trailing edge remains attached to the outer skin. Approximately eleven inches by four inches of the leading edge suffered impact damage and had separated from the door assembly.

Outboard Aft Door

Not attached to door assembly. Door could not be identified.

6.3.6 Right Wing Gear Wheel Well Doors (LG1O)

Inboard Door

There is evidence of cracks and punctures in the outer skin of the door. The rod was fractured at the threaded area adjacent to the door fitting. The aft rod arm had separated from the door assembly. The third and fourth hinges aft of the leading edge had separated from the door assembly.

Outboard Door

This door suffered impact damage at the leading edge and trailing edge. All hinges had fractured. The rod and fitting had separated from the door assembly. The aft inboard corner had separated from the door assembly. The inner skin is cracked running forward where the rod fitting was located. The forward inboard corner structure has separated from the door assembly.

6.3.7 Right Wing Gear Doors (LG1O)

Outboard Door

The outboard door broke into three segments. The outboard comers separated from the door assembly. The forward edge was dented midway.

Inboard Door

The inner skin was cracked and dented.

7.0 Engine Strut

7.1 General Description

All struts, strut to wing, and strut to engine primary structure was recovered from the Green debris area. See Figure A7.20 for identification and tag numbers. The condition of each strut was first examined by the PowerPlant Group and is documented in Powerplant Group Factual Report. The necessary hardware of each strut was disassembled from the engines by the Powerplant Group for engine examination. Following is the factual documentation of the struts by the Powerplant Group prior to disassembly of the strut hardware.

StrutNo. 1:- The recovered piece of the strut was the structure between the forward and aft engine mounts, with both the forward and aft engine mounts still attached. The forward engine mount had a piece of the left side of the fan case and strut. The access panels were missing from the left side.

Strut No. **2:-** The strut was separated from the engine, although it was recovered and returned with the engine. The right side of the pylon had crushing darnage with the skin pushed inward between the internal structure. The skin on the lower left side of the strut was bent outward and the access panels on the left side were missing.

Strut No. **3:-** The strut remained attached to the engine, extending just aft of the fan struts to in line with the turbine exhaust case engine mount rails on the left side and two rib bays further aft on the right side and bottom. The nose section of the strut was missing with the upper skin on the strut bent upwards and to the rear. The lower stringers of the strut were bent towards the right. The bottom of the strut over the engine mount was buckled upwards and the adjacent skin on the right side was buckled inwards. The access panels on the left side of the strut were missing.

Strut No. **4:-** The strut was crushed on the right side and buckled inward on the center of the left side. The engine mount remained attached. to the strut. The front of the strut was crushed axially aft about 5 inches. The assess panels were missing.

The Structure Group documented all the struts, strut to wing and strut to engine primary structure after the disassembly of strut hardware by Powerplant Group.

7.2 Strut No. 1

The No. 1 strut suffered severe impact damage with separation of the aft section from the wing. Darnage occurred to the strut aft box structure from the rear engine bulkhead, nacelle station (NS) 222, to the aft torque bulkhead NS 269, (Fig.A7.2). The upper link, strut upper spar fitting fractured at the forward fuse pin connection and exhibited tensile rupture (Fig. A7.3). Separation of the midspar to wing attachment occurred through both the inboard and outboard midspar primary chord sections common

to each midspar fitting. Fracture of each chord initiated at the forward most row of fasteners of the midspar fitting horizontal duckbill flange. The fracture surface exhibited tension failure with slight bending. Both fractures exhibited evidence of ductile failure. The midspar structure assembly was sooted but free of fire damage except for a remnant of the aft torque bulkhead web that remained attached (Fig. A7.3 and A7. 18).

The diagonal brace strut lower spar fitting fractured at the aft lug attachment and exhibited twisting and bending in an outboard direction (Fig. A7.3). The diagonal brace sustained impact damage to the center of the brace with localized crushing of the tube wall (Fig. A7.3). There was evidence of sooting along the aft length of the brace. Fuse pins were intact at each end of the diagonal brace including the underwing diagonal brace fitting which remained attached (Fig. A7.5).

The engine separated from the strut at the front and rear engine mount as a result of rupture of the fan case frame and the turbine exhaust case ring, respectively (Fig. A7.4), (Refer to Power Plant Group Chairman's Factual Report). Both strut bulkheads and their respective mount attachment suffered no impact damage. The remaining strut structure suffered no impact darnaged except for the aft torque box section (Fig. A7.2).

Wing to strut fitting attachment

Both midspar underwing fittings (Fig. A7.3, A7. 18) remained attached to the lower skin and suffered no impact damage. Both the midspar fittings remained engaged with their respective fuse pins (Fig. A7.5). The wing diagonal brace fitting and wing box internal support fitting separated as one unit from the wing (Fig. A7.3). Both support fittings sustained impact damage. The outboard underwing vertical support fittings had separated in the forward direction with the front spar web, although both units still remained filly attached to the underwing fitting with the fuse pin assembly intact (Fig. A7.5). Both the primary bolts remained intact (Fig. A7. 18). The upper link remained attached to a section of front spar by the upper link fitting. Both the link and the fitting sustained slight damage and deformation including lateral inboard bending of the link. Fuse pins remained engaged at each end of the link assembly and suffered no impact darnaged (Fig. A7.3). The side brace attachment fitting was fractured and bent at the wing lower skin (Fig. A7.2).

7.3 Strut No. 2

All wing to strut, strut to engine, and strut structure was recovered. There was evidence of impact damage to the upper link and upper spar fitting. The impact forces were predominantly in an up and outboard direction which exhibited rupture of the upper link and strut upper spar fitting through lateral bending and compression fractures (Fig. A7.7). The corresponding structural disconnect ruptured the upper spar, rear engine mount bulkhead, and midspar web (Fig. A7.8). Primary separation of the midspar chords initiated at the 121h and 1 't row of fasteners ahead of the inboard and outboard midspar

fitting duckbill flanges, respectively (Fig. A7.7, Fig. A7. 18). The midspar chords exhibited bending in an outboard direction. The lower spar, from nacelle Station 227 rear engine bulkhead, to the aft torque bulkhead exhibited severe impact damage, with separation of the strut lower spar fitting (Fig. A7.6). The lower spar fitting remained attached to the diagonal brace which ruptured at the clevis end common to the wing fitting (Fig. A7.7). Fracture of the diagonal brace also occurred approximately 35" forward of the aft fuse pin exhibiting bending and twisting (Fig. A7.7).

The forward section of the strut box ruptured at approximately NS 142 forward to the forward bulkhead which separated and remained attached to the fan case frame (Fig. A7.7, A7.6). The side brace lug fractured in bending and tension at the wing side attachment (Fig. A7.6). A section of the rear engine mount bulkhead structure remained attached to the turbine exhaust case (Fig. A7.8). Forward and rear engine mount assemblies remained fully intact with no impact damage.

Wing to strut attachment fittings

The inboard midspar underwing support fitting remained attached to the wing box lower skin (Fig. A7.7). There was evidence of some damage at the forward section of the fitting with slight lateral deformation along the longitudinal free flange. The fitting remained intact with the midspar duckbill fitting and the fuse pin assembly (Fig. A7.9). The midspar fitting exhibited no evidence of damage. A large section of the outboard midspar underwing fitting separated (Fig. A7.18) from the wing lower skin. The outboard half of the fitting included a section of the inboard leg. The remaining inboard section remained attached to the wing box skin. The bulk of the fitting disconnected from the wing box skin with the front spar fitting and the fuse bolt that still remained engaged. The fitting separated along the attaching fasteners of the lower skin with fracture separation outboard and some sooting was also present along the forward face of the fitting. The wing diagonal brace fitting was found attached to the lower wing skin with the forward 12 inches fractured and separated with the wing skin due to impact (Fig. A7. 7). A 4-inch outboard section of the diagonal brace clevis lug remained attached with the aft fuse pin still engaged (Fig. A7.7). The recovered upper link fitting had separated from the front spar web (Fig. A7.7). Both fitting and upper link remained secured by the fuse pin and were extensively damaged. The fuse pin exhibited no impact damage.

7.4 Strut No. 3

All wing to strut, strut to engine, and strut structure was recovered. Both the strut midspar fittings remained attached to the wing box underwing fitting with both fuse pins engaged (fig A7. 11). The inboard midspar fitting was undamaged and remained attached to the midspar chord section that had fractured approximately 20 inches forward of the midspar duckbill fitting flanges exhibiting tension and bending in an up and outboard direction (Fig. A7. 19). The strut upper spar fitting (upper link) separated at the net section of the lug in tension (A7. 11). Both fuse pins remained engaged at each end of the upper

link (Fig. A7. 13). The aft end remained intact to the upper link fitting with both fittings being deformed/damaged in an outboard direction (Fig. A7. 11).

The outboard midspar fitting engaged the midspar primary chord with all attachment fasteners fully in place. The aft vertical flange common to the aft torque bulkhead vertical chord had separated completely from the midspar fitting at the stem radius and was bent aft. At approximately 50 inches forward of the midspar duckbill flanges, the midspar chord separated in bending and tension with noticeable indications of outboard direction (Fig. A7. 19). The strut aft torque box section (NS222 to NS301) exhibited evidence of severe impact damage with full separation of the inboard side skin from the aft torque bulkhead to the rear engine bulkhead. The outboard side skin from NS 236 to the aft torque bulkhead had also separated from the structure. The impact damage in this area exhibited, tearing, and general crushing of the structure (Fig. A7. 10). The midspar web was also severely damaged (Fig. A7. 12). The diagonal brace was recovered with both the strut lower spar fitting and the wing diagonal brace fitting attached with their respective fuse pins. All three units were damaged (Fig. A7. 11). The strut lower spar fitting was extensively damaged with the aft attachment flange warped and cracked (Fig. A7. 11). The diagonal brace suffered impact damage and exhibited extensive cracking along the longitudinal direction initiating from each clevis throat radius. The diagonal brace exhibited twisting and bending laterally in the area of damage (Fig. A7. 11).

A 20-inch section of the forward strut box, from NS 148 forward to the forward engine bulkhead (NS 128) suffered impact damage with full separation of the front engine mount bulkhead (Fig. A7. 10). The mount attachment was recovered and remained attached to the fan case frame. Except for the bulkhead skin attachment structure, the bulkhead face and engine mount assembly, including the cone bolt attaching members, remained intact (Fig. A7. 12). The strut was recovered and remained attached to the engine turbine exhaust case. The rear engine bulkhead and lower engine attachment were relatively undamaged.

Wing to strut attachment fittings

The strut No. 3 inboard midspar underwing fitting were recovered and remained attached to the wing box lower skin. This fitting exhibited minor damage with some localized nicks and gouges to the longitudinal flanges just aft of the fuse pin housing boss. The damage is indicative of the strut midspar fitting clevis contact during spring back when the midspar chord fractured (Fig. A7. 19). The outboard midspar underwing fitting partially separated along the longitudinal parting plane in an outboard direction (Fig. A7.1 1), with the forward section of the joint separating from the front spar with the vertical support fittings.

A 2-foot section of the inboard leg of the fitting remained in place on the wing skin. The separated forward joint still engaged the darnaged strut midspar fitting and fuse pin assembly. The diagonal brace underwing fitting separated with the diagonal brace as a

combined unit (Fig. A7. 11). The diagonal brace underwing fitting suffered impact damage. The outboard flange fracture and separation with nicks and gouges to the vertical flange and is consistent with diagonal brace clevis necking (Fig. A7. 11), The upper link fitting separated from the front spar in an outboard direction with a 2-foot section of wing front spar web remained attached. Both lower skin shear were ties fractured and the fitting upper flange to skin fasteners separated in tension. Each leg of the fitting sustained minor deformation. Both fitting halves were secured with the fuse pin assembly which remained undamaged. The forward fuse pin remained engaged at the forward end of the upper link (Fig. A7. 13). The side strut brace member fractured in bending in the aft direction at the wing attachment fitting (Fig. A7. 10).

7.5 **Strut No. 4**

All wing to strut, strut to engine, and strut structure was recovered The inboard midspar fitting was intact and remained attached to the wing box underwing fitting, with the midspar fuse pin engaged. The inboard support of the inboard midspar fitting separated just ahead of the midspar duckbill flanges at the strut midspar chord, (approximately 15 inches forward of the inboard fuse pin). The fracture exhibited tension failure and the chord was bend (Fig. A7. 19). The upper spar fitting lug fractured and separated from the upper link connection at the forward joint (Fig. A7. 15). The fracture surface exhibited tension/ductile failure. The link with both fuse pin assemblies remained attached to the upper link pitch fitting at the front spar (Fig. A7. 17).

The outboard midspar fitting remained attached to the wing box underwing fitting with the fuse pin engaged. The midspar fitting duckbill flanges had fractured along the 4th row of the fasteners of the upper flange from the fuse pin, and the lower flange had separated completely at the most aft juncture (Fig. A7. 19). Both flanges had indications of downward and inboard bending and twisting.

Fracture of the torque bulkhead chord, common to the vertical stem of the duckbill fitting, occurred at a section 16 inches below the fitting stem (Fig. A7. 19). The aft torque bulkhead structure was not recovered except some remnants of chord attached to the lower spar fitting and midspar fittings. The diagonal brace separated at the wing diagonal brace fitting at approximately 12 inches forward of the fuse pin attachment. The 12“ diagonal brace fragment remained attached to the wing fitting with the pin assembly. Fracture of the basic tube section is indicative of bending and twisting action (brace being forced in the aft direction against the flanges of the wing fitting) (Fig. A7. 15). The majority of the diagonal brace remained with the strut and engine case.

The diagonal brace, lower spar fitting, thrust link, and rear engine block fitting suffered severe impact damage. All four units remained in place attached to the turbine case assembly (fig. A7. 16). Both sides of the strut side skin suffered extensive damage with the outboard section missing from the aft torque bulkhead forward of NS 193. The rear engine bulkhead (NS 222) was extensively damaged including the upper spar and

upper forward nose skin (upper spar) with the outboard skin peeled back in an outboard direction (fig. A7. 14). The inboard side skin separated from NS 236 to NS 269, and this section was not recovered. The remainder of the side skin was heavily crushed with the forward bulkhead pushed aft, approximately 5 inches along the forward firewall web (Fig. A7.14).

The forward engine mount was intact and remained attached to the damaged forward bulkhead. Both tangential links were in place at the rear engine mount and turbine exhaust case. The right tangential link was deformed aft (Fig. A7. 16).

Wing to strut attachment fittings

The strut underwing fitting at each location, including the upper link fitting, was found in place with the wing box and suffered minor damage. The outboard strut underwing fitting exhibited extensive inboard bending deformation of the fuse pin attachment lugs. All fittings sustained witness marks and gouge marks to the flange on the aft side of the fuse pin boss from contact during the aft rotation of the midspar fitting clevis. Fuse pins remained engaged at each joint and exhibited no impact damage (Fig. A7. 15, A7. 19). The upper link was intact and remained attached to the wing box front spar fitting (upper link fitting). The upper link sustained localized flange bending damage on each side of the inboard and outboard free flange. Both the fuse pins remained engaged (Fig. A7. 17). The side brace support tube separated at the wing lower skin attachment fitting and was bent in aft direction.

All possible fracture surfaces were visually examined in detail and exhibited ductile failures.

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