

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Aviation Engineering Division
Washington, DC 20594

September 18, 2017

INVESTIGATOR'S FACTUAL REPORT OF INVESTIGATION FOR AIRCRAFT SYSTEMS AND POWERPLANTS

A. **ACCIDENT:** DCA17MA022

LOCATION: Fort Lauderdale International Airport

DATE: October 28, 2016

AIRCRAFT: McDonnell Douglas/Boeing DC-10-10F, N370FE

B. SYSTEMS GROUP:

Investigator: Robert L. Swaim
 NTSB
 Washington, DC

Party Member: Scott Schwartz
 Air Line Pilots Association
 Memphis, Tennessee

Party Member: Steve Haggerty
 Boeing Commercial Aircraft
 Seal Beach, California

C. SUMMARY:

On October 28, 2016, at about 1751 eastern daylight time (EDT), FedEx flight 910, a McDonnell Douglas MD-10-10F, registration N370FE, experienced left main landing gear collapse and subsequent fire in the left wing after landing on runway 10L at Fort Lauderdale–Hollywood International Airport (KFLL), Fort Lauderdale, Florida. The two flight crew members evacuated the airplane after the airplane came to rest on the side of runway 10L and were not injured. The airplane was substantially damaged. The cargo flight was operating under 14 Code of Federal Regulation Part 121 and originated from Memphis International Airport, Memphis, Tennessee.

A Systems Group was not formed. Representatives of Boeing and the Air Line Pilots Association (ALPA) joined the NTSB Systems Investigator to record observations related to the airplane systems.

D. DETAILS OF THE INVESTIGATION:

LANDING GEAR:

The nose gear was found in the down and locked position, with the lower wheel/tire assemblies approximately 2/3 submerged into the soil.

The right main landing gear was found in the down and locked position, resting on grass at the edge of the pavement.

The left main landing gear shock strut (oleo) was broken and folded aft. The leading tires were oriented downward and the inboard wing flap was resting on the inboard tires.¹ (See Figure 1)



Figure 1. The inboard left flap resting on the left main landing gear.

¹ The wheel/tire/brake assembly positions are numbered from left to right by row, so that No. 1 is the left gear, forward outboard tire and No. 2 is the inboard. The No. 3 is the right gear, inboard forward tire and No. 4 is the right outboard. The numbers 5 – 8 positions are also numbered left to right.

The outboard side of the left truck beam had a major crack ahead of the forward axle, on the outboard side. The broken end of the truck beam was between the tire resting on the ground and the bottom pivot of the vertical oleo strut. (See Figure 2)

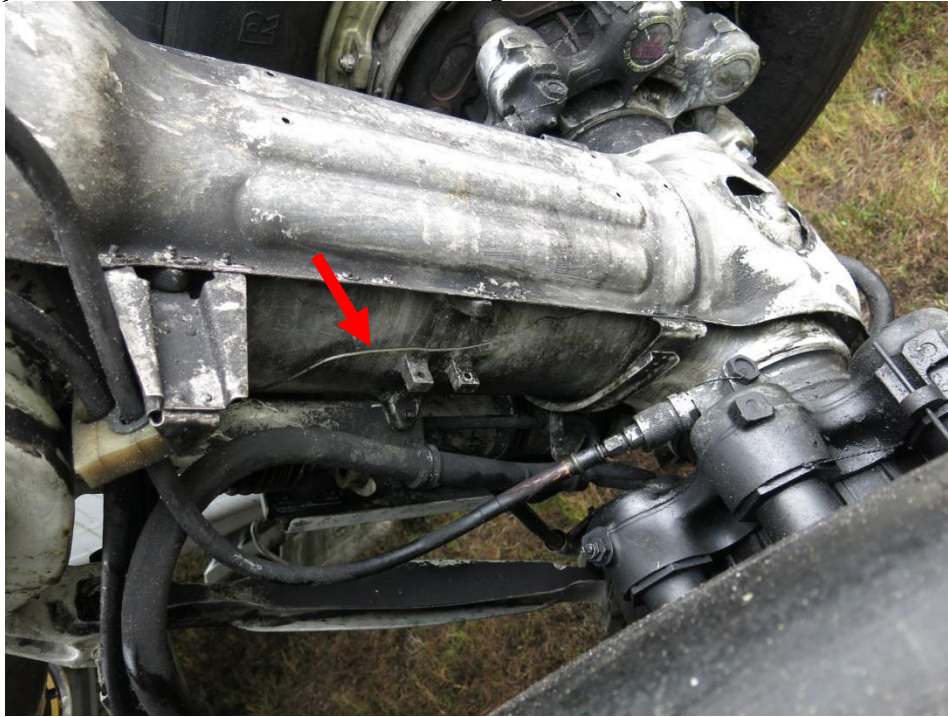


Figure 2. Bottom of left truck beam, showing crack. (Arrow)

The down-lock, side braces, and the end of the retraction rod were found twisted and broken. (See Figure 3) The twisting and fractures were consistent with the break in the main landing gear cylinder which rotated aft. The broken end of the retraction rod did not visibly have fatigue striations.



Figure 3. Broken and twisted downlock assembly and attachment point for retraction actuator.

The tires were all generally in good condition, with minimal operational wear or damage. The tread grooves in each had substantial depth remaining, none of the tire treads had flat spots, and all tires remained pressurized. The outboard forward tire (No. 1) had more shoulder wear, which was consistent with the angle it had been displaced to by the broken landing gear strut; the wear was within serviceable limits. (See Figure 4) Tread damage related to the accident sequence was found, such as the left main gear inboard aft tire (No. 6) had a deep circumferential cut in the shoulder, near where the tire struck the most inboard flap track. (See Figure 5) The left nose wheel tire exhibited more wear than the right.



Figure 4. Tire wear, showing tires No. 1 and No. 2.



Figure 5. Circumferential cut in shoulder of tire No. 6.

Tire rubber transfer marks on the runway could be followed from the resting airplane to before rubber transfers and other marks associated with the left main landing gear collapse. The initial tires marks were dark full tire-width lines which clearly showed each of the tread grooves. The tread grooves and evenness of the rubber transfers to the runway were consistent with function of the anti-skid braking system. The left main gear and the rubber transfers associated with the right main gear remained consistent and evenly proportioned beyond where gouges and other runway marks were consistent with the collapsed left main gear. A rubber transfer along the runway could be followed to the nose landing gear and the left nose wheel tire had more wear than the right nose tire did.

The hydraulic system had been too extensively breached to pressurize, consistent with breakage of the landing gear strut and the extensive fire damage. Without pressure, the state of the brake wear could not be accurately determined. The lengths of the brake wear pins and pistons were consistent with the airplane having available brake material at the end of the landing. (See Figure 6)



Figure 6. Example of brake wear pin (oval) and piston (arrows).

The left main landing gear brake line routings from each of the brakes (No. 1, 2, 5, 6) to the antiskid manifolds were visually followed. The manifolds normally are located at the top portion of the landing gear and the mountings had been displaced by damage. None of the brake lines were found to be crossed. FedEx uses color coded panduits (tie-wraps) to identify hydraulic lines and hoses at three connection points (antiskid manifold, pipe to hose, and hose to brake port) and the following are details of the routing colors found:

Forward antiskid manifold:

- Top port – No. 5 brake (color tagged yellow)
- Second port – No. 1 brake (color tagged red)
- Third port – No. 2 brake (color tagged blue)
- Bottom port – No. 6 brake (color tagged green)

Aft antiskid manifold:

- Top port – No. 5 brake (color tagged yellow)
- Second port – No. 1 brake (color tagged red)
- Third port – No. 2 brake (color tagged blue)
- Bottom port – No. 6 brake (color tagged green)

The wheel and tire identifications from left main landing gear were found to be:

- No. 1 position
 - Wheel (Honeywell) P/N 2609471, S/N 3496
 - Tire (Goodyear) P/N 541K69-2, S/N 22773138 Retread Level R4
- No. 2 position

Wheel (Honeywell) P/N 2609471, S/N 4164
Tire (Goodyear) P/N 541K69-2, S/N 43083136 Retread Level R2
No. 5 position
Wheel (Honeywell) P/N 2609471, S/N 3488
Tire (Goodyear) P/N 541K69-2, S/N 42003136 Retread Level R4
No. 6 position
Wheel (Honeywell) P/N 2609471, S/N 4937
Tire (Goodyear) P/N 541K69-2, S/N 41073134 Retread Level R3

The identification numbers were not collected for the submerged nose tires and wheels, or for the serviceable right main landing gear.

COCKPIT OBSERVATIONS:

The emergency descent strap on the Captain's side was found stowed. The strap on the First Officer's side had been used and investigators pulled the strap into the cockpit to close the window before heavy rain arrived.

As part of the conversion of the airplane from a DC-10 to an MD-10, the cockpit had been retrofit with a full set of electronic flight displays. (See Figure 7)



Figure 7. Cockpit displays in the center area.

The mode control panel on the glareshield had both BAROSET selectors at QNH and both MINIMUMS selected to BARO. The HDG selector was at the AUTO selection and both AFS over ride switches were in the stowed positions.

The standby attitude indicator showed the red OFF flag, with the pitch at +51 degrees, and the roll display was at 21 degrees right wing down. The standby altimeter was set to 1016 MB / 29.99 inches Hg, and the display rested at a display of -20 to -25 feet.

Both hydraulic brake pressure gauges showed zero psi.

The center pedestal was examined. (See Figure 8)

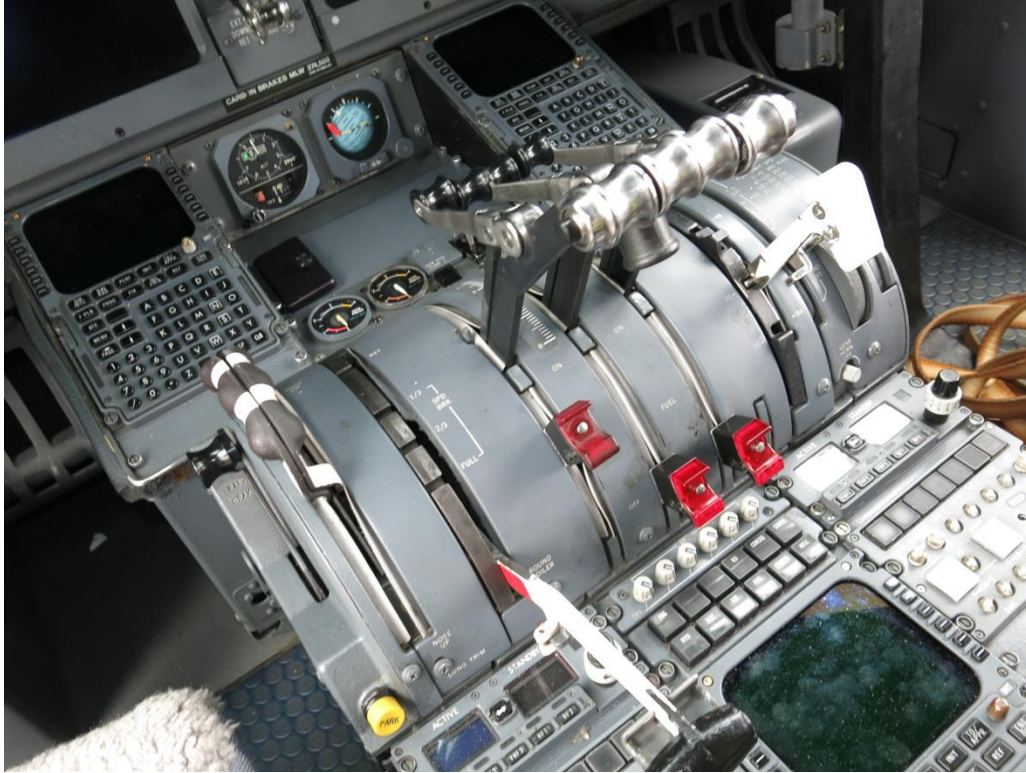


Figure 8. Center pedestal.

The parking brake handle was found stowed.

The forward end of the longitudinal trim handles were 3.25 inches from the forward end (NOSE DN) of the travel range.

The ground spoiler was in the deployed (full aft) position. According to a FedEx check airman, the after landing checklist calls for stowing the handle.

All three throttles were found full aft with the thrust reverser levers fully stowed. As noted in the engine section of this report, all three engine reversers were found in the deployed orientations. The center and right engine fuel cutoff sliders were locked in cutoff. The left engine slider was mid-range and could not be moved. The sliders were connected to the respective engines by control cables and the route of the left engine cables through the pylon had been disrupted by both the orientation of the engine and extensive fire damage.

The flap selector was found at 35 degrees and the slat selector was with the flap selector. The “dial-a-flap” roller was found at zero degrees.²

The aileron trim knob was at one degree right wing down and the rudder trim knob was centered.

The cockpit oxygen mask for the captain was stowed. The door for the first officer’s mask was ajar, with the mask in the box.

² The DC-10 dial-a-flap roller is provided for use during takeoff, and the zero position was consistent with landing.



Figure 10. Overhead panels



Figure 11. Overhead panels



Figure 12. Overhead panels

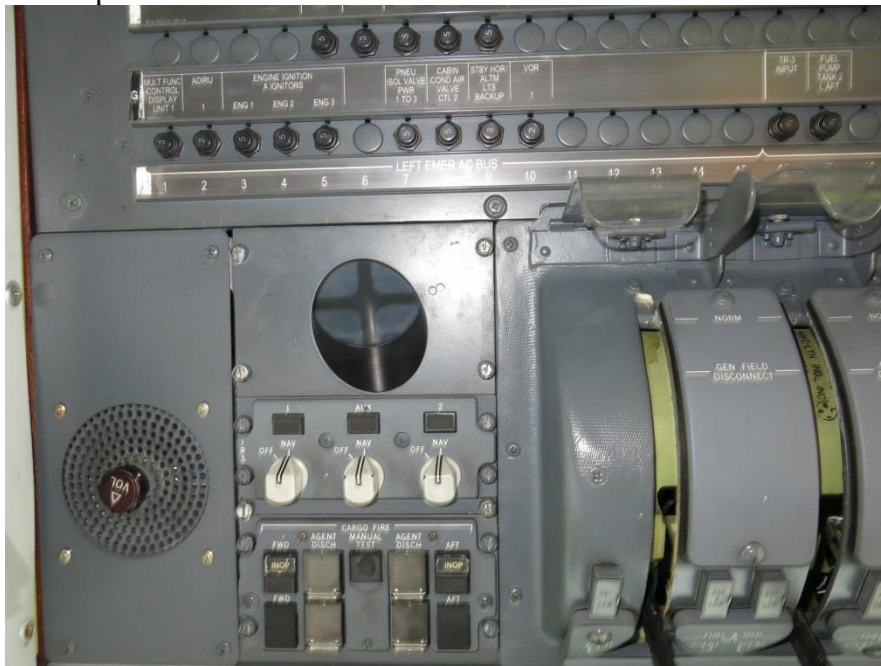


Figure 13. Overhead panels



Figure 14. Overhead panels

CARGO COMPARTMENTS:

The upper deck cargo compartment was entered from the cockpit area. The door was found shut and it opened without binding. Each of the restraining net attachments was found in place. Within the cargo compartment, all of the individual cargo containers were found fastened to the floor restraining system, with all locks up.

The lower cargo compartment doors were opened from the exterior and did not bind. Each of the containers was found locked in place. The bulk cargo compartment was not full and the packages were found to be restrained by netting.

FLIGHT CONTROLS:

The wing flaps were found in extended positions. The orientations in the range of flap track wear in the wings were consistent with finding the cockpit flap control handle in the 35 degree position.

The leading edge slats on both wings were found extended. The slats adjacent to the left engine had been partially consumed by fire.

The spoilers were found in retracted positions.

Portions of each aileron remained. The ailerons were found in trail and fire had consumed portions of the left ailerons.

The rudder appeared from the ground to be undamaged and without major hydraulic leakage.

The horizontal stabilizer and elevators were undamaged. The stabilizer trim was leading edge down beyond the two markings painted on the fuselage and by visually estimating from those marks the trim was about 9-10 degrees airplane nose up. (See Figure 15)



Figure 15. Stabilizer trim markings on right side of fuselage.

RECORDING DEVICES:

Recording devices were removed from the airplane at about 11am on Saturday, October 29, 2016. All of the recording devices were removed from their in-service mountings and all were recovered without damage.

Found on the aft side of the bulk cargo compartment door, Honeywell flight data recorder (FDR), serial number (S/N) SSFDR-10591 and the General Electric combination voice/data recorder P/N 175497-01-01, S/N 61 (See Figure 16)



Figure 16. The mounting locations of the FDR and combination voice/data recorder.

The Allied Signal ground proximity warning system (GPWS) P/N 965-0976-003-224-224, S/N 2401 was recovered from the forward electronic equipment compartment, beneath the cockpit.

The Quick Access Recorder (QAR) recorder contained a PCMCIA card marked FOQA data collection card P/N Z-31-096-01, Rev B, S/N 1198. This was recovered from the forward electronic equipment compartment, beneath the cockpit.

GENERAL ELECTRIC CF6-6K ENGINES AND ENGINE PYLONS:

The engine data plates were not seen because none of the engine cowl doors were opened. Nothing abnormal was noted in the left or right engines when a flashlight was used to examine the interior areas through the hydraulic filter and oil doors, other than fire-related heat and soot damage to the left engine.

All three engines were found with the thrust reverser translating cowls in the full reverse extensions. The left and right engine blocker doors were visually confirmed to be in the reverse positions. No case penetrations existed from uncontained rotating parts of the engines. The right engine appeared to be unaffected by the accident and the fan rotated. Although the center engine could not be accessed for close examination, the engine and entire aft fuselage/tail appeared from the ground to be entirely unaffected by the accident and the fan could be heard turning in the wind.

The bottom of the left engine had two large areas of scrapes. The forward scrape was along the bottom of the cowl doors, and the second scrape extended aft from the aft edge of the thrust reverser blocker vanes. A video of the landing showed that the left engine was initially supporting the airplane with the left engine inlet in normal relation to the fuselage when fire

began near the left wing tip. The skid marks at the bottoms of the cowling doors were consistent with this orientation. (See Figures 17, 19, and 20)



Figure 17. Two areas of scraping on the bottom of the left engine were found. (See ovals) Scrapes existed on bottom of engine cowling doors and a scraped crush line was along the aft edge.

Review of videos showed that after fire existed near the wing tip a fireball erupted at the left engine and the fire was large enough to obscure the image of the engine. (See Figure 18) When the engine was again visible it had the inlet shifted upward so that the engine was at the orientation of how it came to rest.



Figure 18. The still image from a video is of the airplane nose, and from the airplane this image would have been at an orientation of about 11 o'clock (left of straight ahead). Two fires are

visible, one near the tip of the left wing and a larger second fire which erupted in the area of the left engine.

The left engine and pylon assembly was found oriented with the inlet upward and trailing end of the pylon near the ground. The aft pylon attach bracket had broken and the two pylon attach points at the forward wing spar were intact. A crush line existed from the aft edge of the thrust reverser vanes to what had been the centerline of the core exhaust. (See Figures 19 and 20)



Figure 19. Crush line of the left engine from rear.



Figure 20. Left engine crush line from side and orientation as found. The thrust reverser translating cowl is open and the outboard extent of the fire is visible. The burned outboard side of the pylon is visible.

The left pylon fuel tube was found torn and partially consumed by fire. (See Figure 21) The firewall shutoff valve was found in the closed position.

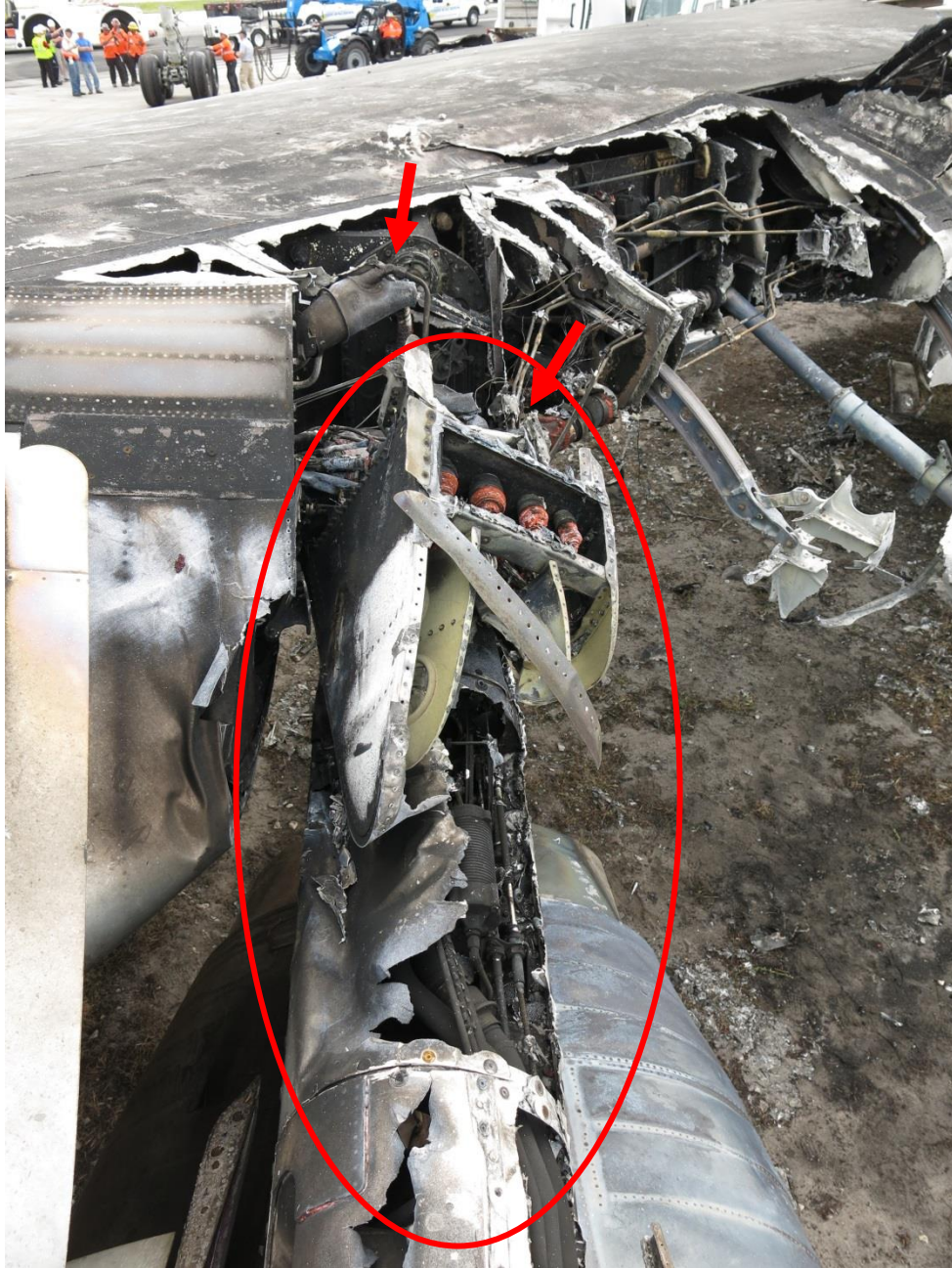


Figure 21. This view is from above the left engine and looks aft, showing the left engine pylon (oval), top of the engine, and left wing leading edge. The arrows point to the torn and partially consumed ends of the pylon fuel tube.

The outboard translating cowl had been extensively fire damaged and partially consumed by fire. The inboard translating cowl had relatively no fire damage more than a foot above where it rested on the ground. The thin aluminum top cover of the engine pylon had melted between stiffeners on the outboard and top surfaces. Beneath the forward wing spar was extensive melting damage within the pylon which was localized and beneath where the wing skins and forward spar had opened.

The left engine fan could not be moved by hand. The inlet surrounding the tips of the fan blades had abrasion from use without heavy scrapes or tip contact marks. The leading edges of the fan blades had light scouring typical of normal use, and were otherwise smooth without impact marks or tip damage. Behind the fan, the visible inlet guide vanes and blades were unaffected by the accident.

The complete turbine case had broken and been displaced about five inches up from the rest of the engine. Turbine blades were found scattered along the runway where the fire debris began and when viewing the turbine section from the exhaust, two complete rows of turbine blades were missing. Many of the root portions of the missing blades were in the discs. A third partial ring of blade sections which appeared to be exhaust vanes had dislodged from the mounted orientation; the lower portion of these blades were not in the exhaust case. (See Figure 22)



Figure 22. View into exhaust of left engine.

FUEL TANK EXPLOSION AND DEBRIS:

A portion of the top wing skin separated from the wing and landed outboard of the wing tip. Three fragments were found; one large and two small. The large panel was irregularly shaped and the outer dimensions were 25' 6" spanwise by 8' 11" chord-wise. (See Figure 23) The two small fragments were about 9 inches in the longest dimension, one of which was skin material and the other was the edge of a wing rib. (See Figure 24)



Figure 23. Panel of left wing top wing surface.



Figure 24. One of two small wing rib fragments, showing toe of boot for scale.

The large piece landed 44 feet outboard of the wingtip, and 54 feet forward of the leading edge of the tip. This was in line with the joint between the nose cowl and cowl doors, and 95 feet outboard of the (displaced) engine centerline. The small fragments landed almost directly behind the large piece with the aft-most straight outboard of the wing tip, with the aft-most 66 feet aft of the center of the large panel. Using the airplane tail as scale and utilizing still images from videos of the explosion, the upper skin panel reached a height of about 140-150 feet. (See Figure 25)



Figure 25. Exemplar still image taken from a video, showing the wing panel visible above MD-10 at peak of height after separating from the wing. For scale, airplane drawings indicate that the top of the tail is about 75 feet tall.

On the top surface of the wing, the inboard end of the hole was at about wing station XORS 433. This was directly ahead of the joint between the inboard aileron and outboard flap. (See Figures 26 and 27)



Figure 26. The extent of material missing from the top of the left wing is viewed from inboard to outboard. Buckled ribs and fragmented structure are visible.



Figure 27. View of hole toward fuselage from outboard wing, showing a person for scale.

Looking down into the remaining structure and beneath the upper skin, inboard of the check bulkhead, the wing ribs had been displaced outboard. The fuel vent tubes in tank 1 had been

crushed flat. In the area of the fuel tank between the pylon and check bulkhead, the upper skin was displaced upward and lower skin displaced downward, with rows of fasteners missing from each. (See Figure 28)



Figure 28. View inboard from hole in left fuel tank, showing three ribs outboard displaced toward camera.

The most intense heat damage was on the wing spar, immediately outboard of the left pylon, at about XORB 299. In this area, the leading edge slat and wing leading edge were consumed beneath where the upper wing skin separated from the leading edge spar. Aft of this location, the upper wing skin was displaced upward and the lower skin displaced downward, rows of top and bottom surface fasteners were missing, and the flap pivot mount had been displaced from the bottom of the wing. (See Figure 29)



Figure 29. Downward bulge in lower wing skin visible above investigator's hand.

Other separations of the upper and lower wing skins from the leading and trailing edge spars were also seen. The lower wing skin split from the forward spar at the pressure fueling door panel. (See Figures 30 and 31)

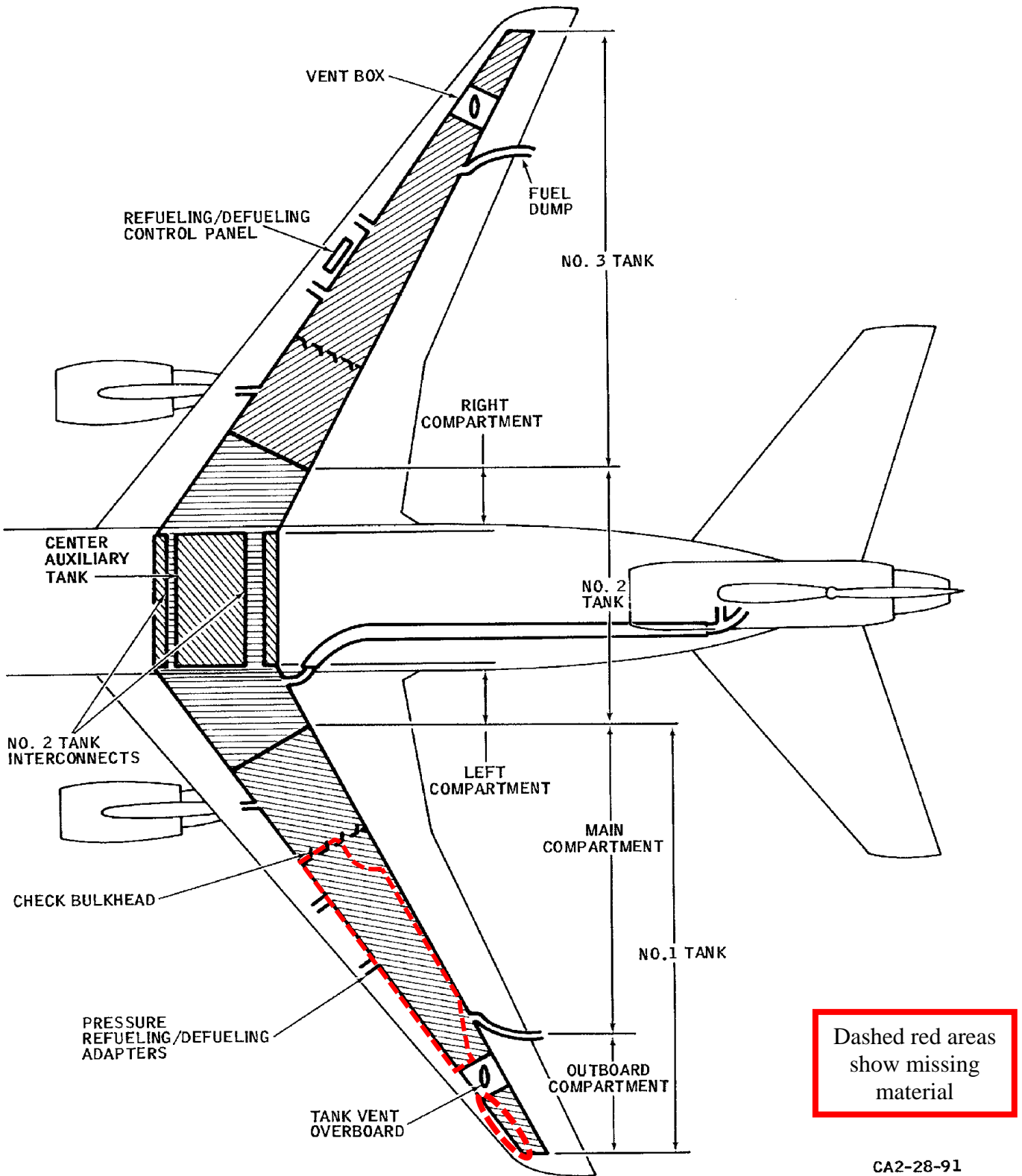


Figure 29. Lower wing skin separated from forward spar. Note left engine for orientation.



Figure 30. Split of lower wing from spar, immediately outboard of left pylon. Note downward bulge of lower wing skin to the right of the arrow.

The areas of missing material were laid on illustrations of the wing. (See Figures 31 and 32)



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Figure 31. Missing wing material in relation to fuel tanks. Source illustration in Attachments.

RUNWAY CORRELATION WITH FIRE:

Videos from the landing correlated with soot and other damage on the runway to show that a line of fire existed near the wing tip before a second fire began at or near the left engine. The initial burn marks on the runway were at the spacing of the left wing vent, prior to where the wing tip contacted the ground. (See Figure 33)

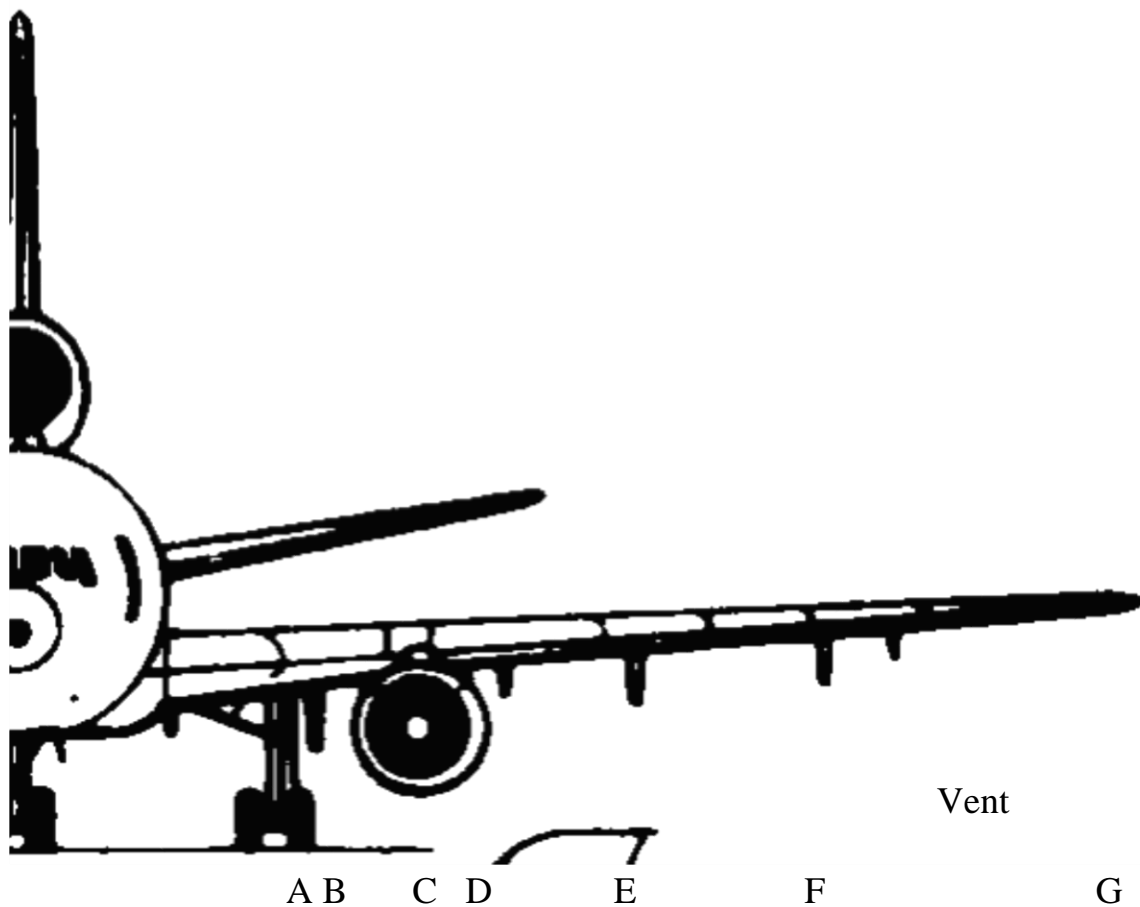


Figure 33. Alignment of runway scrape marks with aircraft features, to relate fire damage.

Burn lines were related to scrapes along the runway, which were measured both from the inboard main landing gear tire track and from the outboard scrape of the aileron. The lines and scrapes

were approximately found to align with the following wing features outboard of a scrape which led to the landing gear door:³

- A. 5'2" Center of outboard tire track.
- B. 10' Bottom edge of landing gear door (displaced) with track leading to the door itself
- C. 14'9" Wide trail of engine cowl scrapes and skin fragments
- D. 23'6" Lighter scrape aligning with flap trailing edge
- E. 36' Flap hinge alignment with gouges on runway
- F. 45' Flap hinge alignment with brown line on runway
- G. 60' Outboard tip of aileron on white runway edge line near wing tip

Two lines of burn marks were found along the runway, which correlated with the video. The outboard was at the span distance of the left wing vent, between F and G). Near where the tracks aligning with the bottom of the engine became suddenly more severe and turbine blades were found, the second line of fire began (C to outboard of D). When the line of travel was less than half the distance to the airplane resting place, the width of fire near the vent suddenly broadened to beyond the wing tip. Examination of the bottom wing skin gouges of about the width of runway lights and found that the bottom of the tank had opened ahead of the outboard left aileron and to the wing tip. This area is an outboard portion of the #1 fuel tank, which extends to inboard of the engine. (See Figure 34)

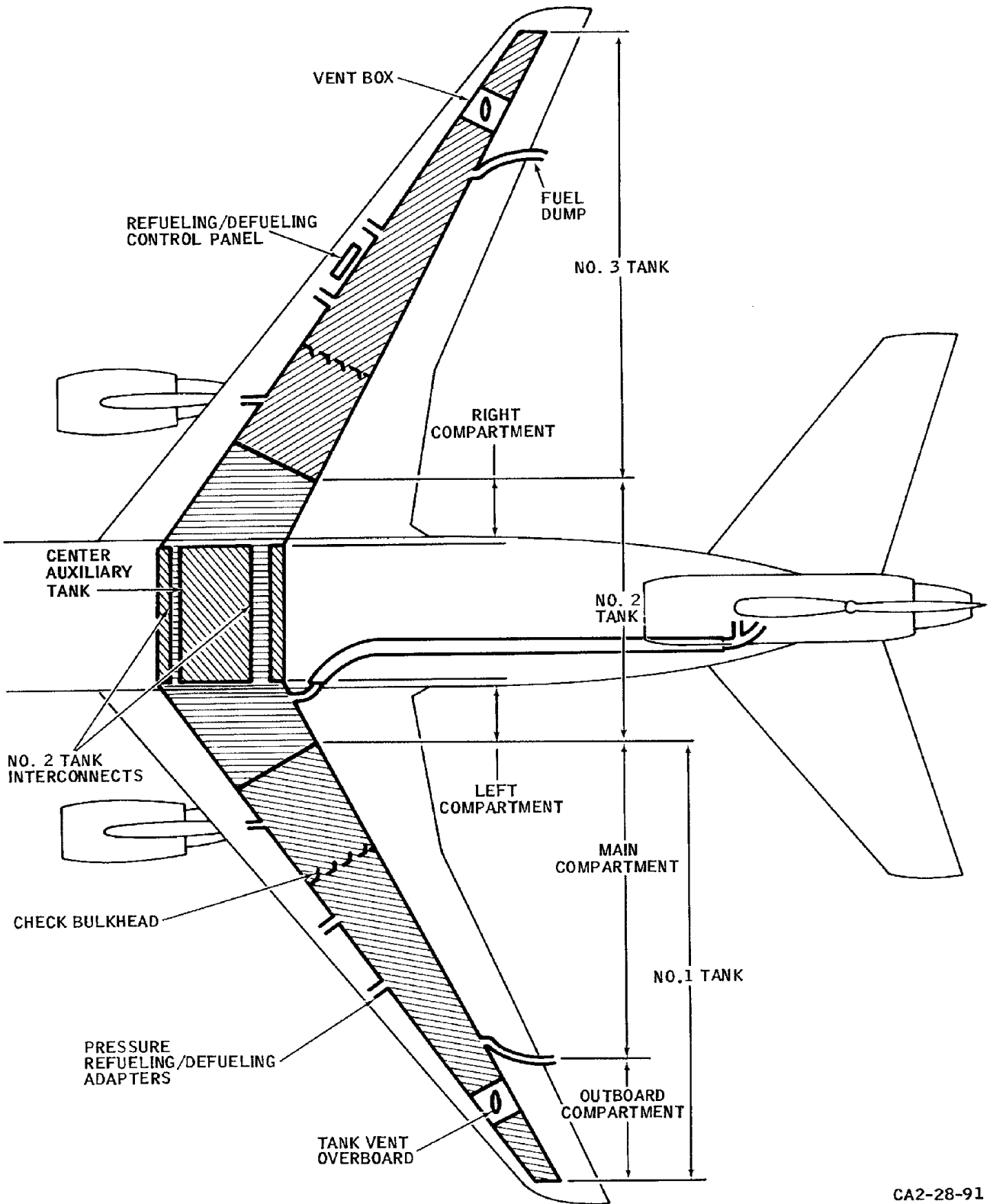
³ If these measurements conflict with those of the Structures Group, the Structures Group Notes will prevail.



Figure 34. Bottom of left wing tip, showing gouges (arrows) and open bottom of fuel tank.

Robert Swaim
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Aircraft Systems Engineering

ATTACHMENTS



CA2-28-91

Illustration titled as follows:
 MD-10 Aircraft Maintenance Manual, Integral Fuel Tanks - - Schematic Figure
 1/28-10-00-990-801 (Sheet 1 of 2), 28-10-00, Page 3, Oct 01/2014

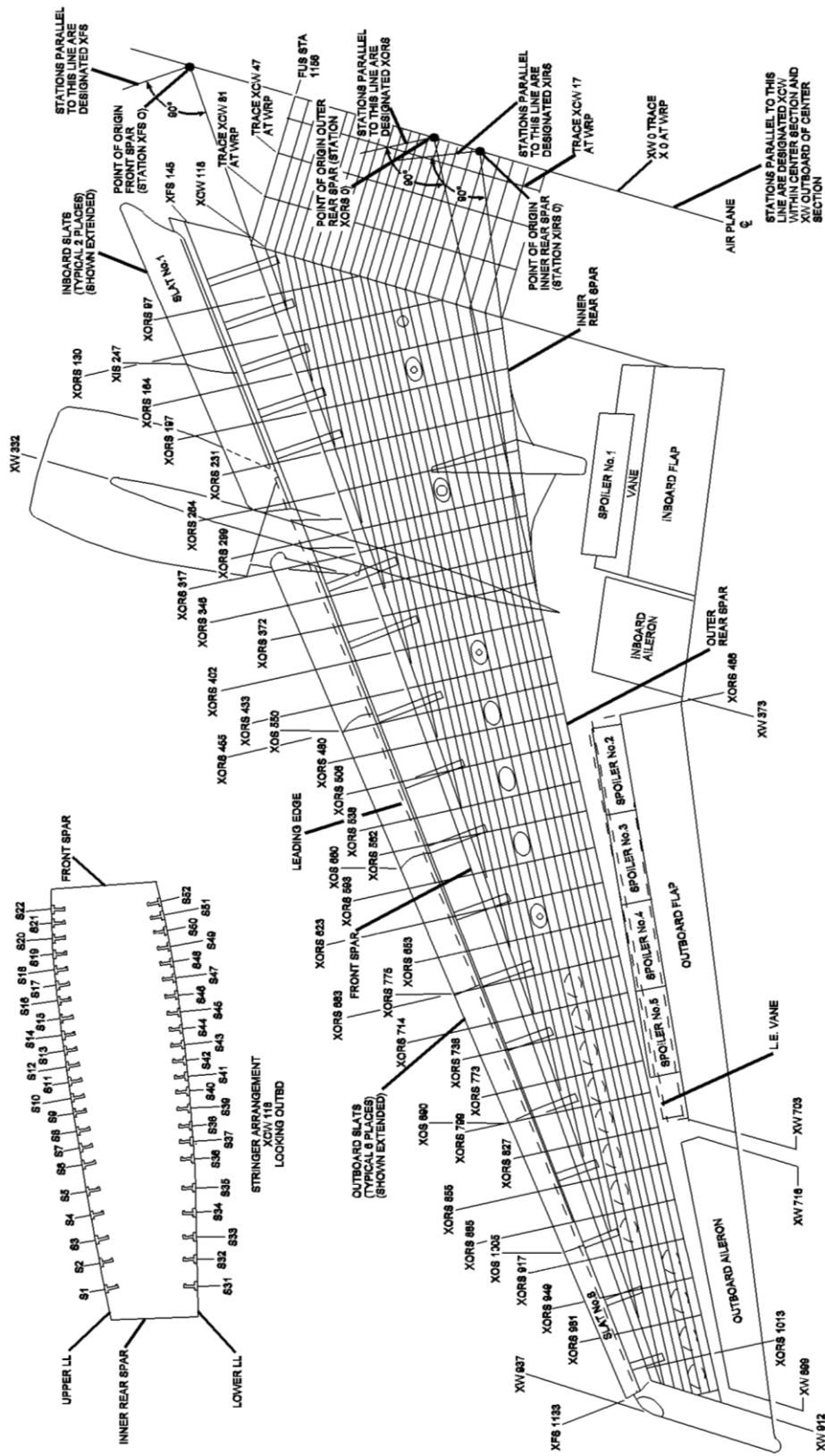


Illustration titled as follows:
 MD-10 Aircraft Maintenance Manual, Wing - - Station Diagram
 Figure 2/06-40-00-990-802, 06-40-00, Page 6, Oct 01/2014