NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

October 4, 2002

Systems Group Chairman's Factual Report
DCA02MA054

A. ACCIDENT

Location:	Tallahassee, Florida
Date:	July 26, 2002
Time:	0540 Eastern daylight time (EDT)
Aircraft:	FedEx Flight 1478, a Boeing 727-232, N497FE

B. SYSTEMS GROUP

Chairman: Tom Jacky
National Transportation Safety Board
Washington, DC

Members – Tallahassee, Florida Activities (July 27, 2002 – August 1, 2002)

Member: Bob Brown
Air Line Pilots Association (ALPA)
Memphis, TN

Member: Frank Matthews
Boeing Commercial Airplane Group
Seattle, WA

Member: Scott Foster
FedEx Express
Memphis, TN

Member – Washington, D.C. Activities (August 27, 2002)

Member: Scott Foster
FedEx Express
Memphis, TN

C. SUMMARY

On July 26, 2002, at 0545 eastern daylight time, a FedEx B-727, N497FE, crashed on final approach to Tallahassee Regional Airport, Florida. The airplane was operating as Flight 1478 from Memphis, Tennessee, to Tallahassee. The airplane crashed short of runway 9, and was subsequently destroyed by impact and post-crash fire.

The systems group met at Tallahassee, Florida from July 27, 2002 to August 1, 2002 to document the accident airplane. As part of the investigation, the group met at the FedEx facility at the Tallahassee Regional Airport on July 28, 2002 and July 31, 2002 to inspect and document two additional FedEx B-727 airplanes, N486FE and N499FE. At the accident scene, the group excavated the flight deck, electric equipment (E & E) bay, and the wreckage path for components for further investigation. The group also examined and documented the airplane's relevant systems.

The systems group met at the National Transportation Safety Board in Washington, D.C. on August 27, 2002 to inspect the flight instruments removed from the accident airplane and in the NTSB Materials Laboratory. The flight instruments inspected were:

1) Captain's electric mach/airspeed indicator,
2) Captain's electric altimeter;
3) Captain's radio altitude indicator;
4) Captain's clock;
5) Captain's upper and lower rudder position indicator;
6) Engine pressure ratio gauge, engine unknown;
7) First Officer's mach/airspeed indicator;
8) First Officer's pneumatic altimeter;
9) First Officer's radio altitude indicator.

For each instrument the glass face was removed, exposing the instrument face beneath. The group members then assessed the instrument face indication.

D. DETAILS OF INVESTIGATION

1. Description of Altimetry Systems

A. Radio Altimeter System

The radio altimeter system provides an accurate measurement of absolute altitude from 2500 feet above ground level (AGL) to touchdown and is used primarily during the approach and landing phases of flight. The airplane is equipped with a single radio altimeter transmitter-receiver and two flight deck radio altitude indicators. The radio altimeter transmitter-receiver is located in the electronics compartment (E & E bay) on the E5-4 equipment rack. The radio altimeter determines absolute height above ground by use of a two antennas – a transmit and a receive antenna, each located on the belly of the airplane, just aft of the electronics compartment access door.

The captain and first officer are each provided a radio altitude indicator, located on the captain's P1-3 and the first officer's P3-3 panels. The radio altitude indicator will continuously display the absolute altitude within a range of zero to 2500 feet. Above 2,500 feet the altitude pointer is hidden behind a pointer mask.

An alert light will illuminate when the airplane descends below the height preselected by using the bug on the outer ring of the indicator face. To alert the flight crew of a selected decision height or minimum descent altitude (MDA), the light cannot be extinguished once it illuminates except by rotating the bug below the existing altitude.

A Collins radio altitude transmitter-receiver, part number 522-3698-014, serial number 7821, was recovered from the wreckage. The unit was subjected to fire and impact damage. In addition, the radio altitude transmit and receive antennas were recovered from the airplane wreckage. The antennas were removed by cutting through the airplane fuselage belly.

FedEx provided schematic drawings of the radio altitude indicator, electronic compartment shelf position of the radio altitude transceiver, and position of the radio altitude antennas. The drawings are included in Attachment 1.

B. Pitot Static Altimeter System

The pitot static system has three heated pitot tubes: one on the left forward fuselage for the Captain's system and two on the right forward fuselage for the First Officer's and Auxiliary systems. There are six heated static ports, three on each side of the airplane, to provide balanced static inputs. A schematic drawing of the airplane's pitot static system is included in Attachment 2.

The captain's pitot tube provides input to the airplane's central air data computer (CADC). The captain's static system also provides input to the CADC. The captain's altimeter, mach/airspeed indicator, and traffic alert-collision avoidance system/inertial vertical speed indicator (TCAS/IVSI) are electric instruments that receive CADC information. A knob on the electric altimeter instrument face sets local barometric pressure.

The first officer's pitot static system provides input to the first officer's pneumatic mach/airspeed indicator. The first officer's static system provides input to the first officer's TCAS/IVSI and pneumatic altimeter. A knob on the pneumatic altimeter instrument face sets local barometric pressure.

An auxiliary system provides static pressure to the cabin altimeter/differential pressure indicator, cabin automatic pressure controller and may be selected as an alternate static source by the first officer. An ambient sense static port provides static pressure to the equipment cooling blower controller switch.

The pitot tube on the captain's side was relatively undamaged. The pitot tubes on the first officer's side were heavily damaged with grass jammed into both sides.

The angle of attack sensor (AOA), located on the first officer's side of the airplane, was found at a position of approximately 45° leading edge down.

2. Description of Ground Proximity Warning System (GPWS)

The Ground Proximity Warning System (GPWS) automatically warns the flight crew of a potentially dangerous flight path relative to the ground beneath the airplane. The GPWS computer continually monitors system inputs and compares them with pre-programmed warning envelopes. The GPWS will provide a visual and aural alert to the flight crew whenever one of the following thresholds is exceeded between 50 and 2,450 feet radio altitude:

Mode 1 – Excessive Descent Rate with a "Sink Rate" aural warning;

Mode 2 – Excessive Terrain Closure Rate with a "Terrain" aural warning;

Mode 3 – Altitude Loss After Takeoff or Go-around with a "Don't Sink" aural warning;

Mode 4 – Unsafe Terrain Clearance During high speed flight or while not in the landing configuration with a "Too Low Gear" aural warning;

Mode 5 - Below Glideslope Deviation Alert with a "Glideslope" aural warning;

Mode 6 – Bank angle and altitude callouts;

Mode 7 – Windshear determination with "Windshear" aural warning.

Red "PULL UP" lights, located on the captain's and first officer's instrument panel, accompany aural alerts and warnings for modes 1 through 4. Amber "BELOW G/S P-INHIBIT" lights, located below the "PULL UP" lights on the captain's and first officer's instrument panel, indicate that the aircraft is greater than 1.3 dots below glideslope. The lights may be pressed to inhibit or cancel the glideslope-alerting mode. Finally, a "GPWS INOP WINDSHR" light, located on the first officer's instrument panel, illuminates during GPWS system self-test and to indicate a malfunction in the GPWS (or windshear) detection system.

The GPWS will not warn for landing short of the runway if airplane is in landing configuration and descending at a normal rate or flight directly towards a sheer cliff with no preceding rising terrain.

The GPWS computer receives inputs from the following:

-Captain or number 1 radio altimeter,

-Number 1 air data computer system (altitude rate and mach/airspeed),

-Number 1 navigation receiver glideslope signals,

-Landing gear and flap positions.

The loss of one of these inputs will deactivate only the affected mode or modes.

A Sundstrand Data Corporation ground proximity-warning computer (GPWC), part number 965-0876-001-B05-B01, serial number unknown, was recovered from the wreckage. The unit was crushed and damaged by fire. The airline indicated the GPWS computer is located in the electronics compartment (E & E bay) on the E5-4 shelf.

3. Airframe

The left wing remained attached to the aircraft structure and exhibited fire damage on the area of the wing closest to the fuselage.

The right wing was separated from the airplane and destroyed by impact. Components of the right wing structure were identified in the wreckage path. The right horizontal stabilizer was also damaged by impact. Portions of the horizontal stabilizer structure were found in the debris field.

The left cabin (L1) door, Boeing part number 50-7945-177, serial number BN955, mod status 52-11 was found open with the door handle in the closed (or right-hand side) position. The emergency slide was found in the debris field approximately 100 feet from the airplane. The L1 door exhibited no evidence of fire damage.

4. Auto Flight

The autopilot control panel was located in the flight deck wreckage. The panel was damaged by impact and fire. The aileron and elevator switches (paddles) appeared to be in the down or "disengaged" position.

The altitude pre-selector was located in the airplane wreckage. The unit was damaged by fire and an assessment of the unit's indication was not possible. The first officer's approach progress display panel was recovered, but due to impact and fire damage no assessment of panel indication was possible.

5. Communications

The aft electronics instrument panel, including the pilot's communication panel, was located in the wreckage. The panel included the captain's and first officer's VHF radios and the captain's and first officer's audio selector panels. The panel was severely damaged by fire with most switches melted, so no assessment of component indication was possible.

No communication components of the overhead instrument panel were located in the wreckage.

A portion of the flight engineer's lower instrument panel was found. The panel included the flight engineer's audio selector panel. The panel was damaged by fire so no assessment of indication was possible.

A headset connected to the first observer's audio selector panel was found hanging through the opened captain's window. The headset was damaged by fire.

6. Electrical Power

Due to the fire damage to the flight deck, no electrical power system panels or controls were recovered. The P-18 circuit breaker panel was located in the wreckage but fire damage to the panel prevented assessment of circuit breaker position.

Several E&E bay electrical components were recovered. These items included the battery charger, Westinghouse voltage regulator, several small electrical junction boxes with 3 connections, the bus panel protection box, electric panel protection box, Mark 125 Load Controller, and electrical converter unit. The panel protection electrical system (Westinghouse part number 902F242-45, serial number RL1603) was also recovered.

7. Equipment and Furnishings

The airplane's main cargo door, located on the forward left fuselage, aft of the flight crew entrance door, was flush with the fuselage and appeared closed. Each of the eight door locking mechanisms was secured and locked. The barber pole indicator on the outside of the cargo door was intact; however, the sliding center indicator was not observed due to accumulation of soot and/or fire damage to the inside of the indicator.

The forward right hand side belly cargo door was closed.

Portions of the airplane's 9-G netting at the front of the cargo area and just aft of the flight crew entryway were located in the main wreckage. Several of the net's metallic attach fittings were located in the wreckage. The fittings did not indicate physical damage. Due to the severe fire damage of the cargo area of the airplane, no portions of the fabric netting were located.

Eight cargo locks were located in the wreckage. All of the locks exhibited fire damage. Three of the locks were too damaged for assessment of indication. Two of the cargo locks indicated a down or unlocked position while three of the locks indicated an up or locked position.

The cargo section of the airplane was severely fire damaged. The cargo continued to smolder several days after the accident. The cargo appeared to be evenly distributed

through the cargo hold and did not appear shifted to either the forward or aft portions of the airplane.

The airline provided paperwork regarding the accident flight's cargo weight and distribution in the cargo hold. The paperwork is included in Attachment 3.

8. Fire Protection

None of the flight deck fire indicators or panels were located in the wreckage. The remains of a fire extinguisher were found in the wreckage.

A Systron Donner smoke detector panel with six boxes was recovered from the wreckage. Each of the six boxes was a part number 7740-01 with various serial numbers.

9. Flight Controls

A. Flight Control System Description

The primary flight controls are hydraulically operated from a set of dual controls in the flight deck. The ailerons are powered by two independent hydraulic systems, A and B, using a single power control unit (PCU) with dual actuators. Either system alone can provide full control capability. The elevators are independent of each other and are each powered by a dual tandem actuator. Each actuator is powered by hydraulic systems A and B and can provide full control capability with either hydraulic system supplying the actuator. There are two separate rudders, upper and lower. The upper rudder is powered by hydraulic system B using a single PCU. The lower rudder has two PCUs, one powered by hydraulic system A and the other powered by thee standby hydraulic system. The standby PCU can only be used if system A pressure is absent.

When either the captain's or first officer's control wheel, control column, or rudder pedals are moved, attached cables and linkages position the inputs to the corresponding flight control surface PCU. Control systems feel forces are produced mechanically.

In the event that both hydraulic systems fail, the ailerons and elevators will revert to manual operation by use of control tabs; no manual reversion for the rudder is provided. However, the standby hydraulic system provides power to the lower rudder if hydraulic system A fails.

The airplane does not have trim tabs. Pitch trim is accomplished by changing the angle of the horizontal stabilizer. Aileron and rudder trim is accomplished by means of mechanical trim, centering, and feel systems.

Each wing has seven hydraulically operated spoilers. On each wing, the five outboard spoilers are flight spoilers that provide roll control (along with the ailerons), and are also used as speed brakes in flight and on the ground. The two inboard spoilers are

operated after touchdown as speed brakes and lift destroyers.

The leading edge flaps, leading edge slats, and trailing edge flaps are hydraulically driven. In the event of a hydraulic system loss and alternate system is available to electrically extend the training edge flaps and position the leading edge flaps and slats control valve to the extended positions. The standby hydraulic system is used to extend the leading edge flaps and slats.

A schematic drawing of the airplane's flight control components is included in Attachment 4.

The accident airplane's fuselage was broken in two locations. Due to impact and fire damage to the airplane, continuity of the primary flight control cables could not be accomplished.

The captain's and first officer's control columns, wheels, and supporting linkages were not found in the wreckage. The captain's rudder pedals were not found in the wreckage. The first officer's rudder pedals were located in the wreckage but the first officer's brake pedals were not found. The center aisle stand was located in the wreckage.

B. Pitch Control Surfaces

Pilot input to either of the control columns provides control input to the two elevator PCUs via control cables and linkages that synchronize the elevator movements.

Each elevator has a tab. The tabs are normally locked by hydraulic power and operate as balance tabs. If hydraulic power is not available, the tabs unlock and are controlled manually through cables and linkages and therefore become control tabs.

The captain's and first officer's control columns were not located in the airplane wreckage. Due to the damage of the airplane, no assessment of the continuity of the elevator control cables from the flight deck to the tail section of the airplane was possible.

The left and right elevators were subjected to fire damage. Approximately one-third of the right elevator was sheared from the airplane, and the outboard approximately one-quarter of the left elevator was sheared from the horizontal stabilizer. The left elevator balance weight was located near the airplane. The left and right elevator tabs were located on the airplane and appeared faired with the elevator.

The right elevator power control unit was examined on the airplane. The part and serial number were not visible through the access panel. There were no visible indications of fire or physical damage to the unit or evidence of a major hydraulic leak. The unit was connected to all linkages. The actuator rod was extended about 3⅝". The linkage to the elevator tab was connected and was moved by hand. The elevator position sensor for the FDR was observed and appeared undamaged.

The left elevator power control unit was examined on the airplane. The part and serial number were not visible through the access panel. There were no visible indications of fire or physical damage to the unit. The PCU was connected to all linkages. The actuator rod was extended 3¾". The linkage to the left elevator tab was connected and was moved by hand. The elevator position sensor for the FDR was observed and appeared undamaged.

C. Lateral Control Surfaces

Each wing has an inboard and outboard aileron. Roll control is augmented by flight spoilers, which move proportionally to aileron movement.

Both inboard and outboard ailerons have balance tabs that reduce required control forces. If both hydraulic systems are not available, the inboard aileron tabs unlock and operate as control tabs. Flight spoilers will be inoperative. When both hydraulic systems are unavailable, the flight crew operates the aileron control tabs manually through cables.

The positions of the outboard trailing edge flaps dictate the operation of the outboard ailerons. When the flaps are fully retracted, the outboard ailerons are locked in the faired position. As the flaps are extended, the range of the outboard ailerons is progressively greater, which provides greater roll control at lower airspeeds.

The captain's and first officer's control wheels were not located in the airplane wreckage. Due to the damage to the airplane, no assessment of the continuity of the aileron control cables from the flight deck inputs to the ailerons was possible. The aileron trim linkage was located on the flight deck center aisle stand, but due to impact and fire damage no assessment of trim position was possible.

The left outboard and inboard ailerons were located attached to the airplane's left wing. There were no visible indications of impact or fire damage to the ailerons. Both ailerons were noted in a trailing-edge-up position.

The aileron power control unit was found in the wreckage. The PCU was damaged by fire.

D. Directional Control Surfaces

The upper and lower rudders are hydraulically powered and assisted by two full-time series yaw dampers. The upper rudder PCU is powered by B system hydraulic pressure only, while the lower rudder is normally powered by A system hydraulic pressure or alternately by the standby hydraulic system. The standby hydraulic system does not have yaw damper function.

The yaw dampers move the rudders proportionally opposite to the yaw rate of the

airplane and do not move the rudder pedals.

The captain's rudder pedals were not located in the airplane wreckage. The first officer's rudder pedals were located in the wreckage but the first officer's brake pedals were not found. Due to damage to the airplane, no assessment of the continuity of the rudder cable to the vertical stabilizer was possible. The rudder trim linkage was located on the flight deck center aisle stand, but due to impact and fire damage no assessment of position was possible.

The upper and lower rudders were located attached to the airplane. The rudder surface appeared to be fully intact and absent of any substantial damage other than sooting from smoke. Although both rudders were scorched from fire, there were no visible indications of impact damage to the surfaces. The trailing edge of the lower rudder was found displaced approximately 6 inches to the left of the rudder neutral point.

The upper and lower rudder tabs were found attached to the airplane. Although the tabs were scorched by fire there were no visible indications of impact damage to the surfaces. The trailing edge of the lower rudder tab was displaced approximately 22 inches to the left of the rudder neutral position.

The upper rudder PCU, part number 59100-5009, Boeing part number 10-60503-12, serial number 2722, was visually inspected on the airplane through an access panel. No measurement of the actuator extension was possible through the access panel. However, the upper rudder was free to move by hand and linkages were connected. The PCU did not exhibit any visible indication of impact or fire damage and appeared to be in good condition.

The lower rudder PCU, part number 59100-5013, Boeing part number 10-60503-13, serial number 2343, was visually inspected on the airplane through an access panel. No measurement of the actuator extension was possible through the access panel. However, the lower rudder was free to move by hand and all linkages connected. The PCU did not exhibit any visible indication of impact or fire damage and appeared to be in good condition.

The stand-by rudder actuator was visually examined on the airplane through an access panel. No part or serial number was visible through the access panel. The actuator did not exhibit any visible indication of impact or fire damage and appeared to be in good condition.

E. Horizontal Stabilizer

The horizontal stabilizer may be operated by the main electric motor at a "fast" trim rate, the autopilot/cruise trim motor at a "slow" trim rate, or manually by cables. Trim switches on either control wheel actuate the main electric trim motor. Manually operated trim wheels on both sides of the throttle quadrant are connected by cables to the stabilizer

actuator mechanism and will move whenever the stabilizer is moving.

The horizontal stabilizer flight deck input linkage was located in the flight deck wreckage. Due to fire damage no assessment of trim input position was possible.

The vertical stabilizer is marked with three detent markings near the stabilizer leading edge surface. According to FedEx maintenance and operations staff, these marks are intended to provide visual indication of stab deflection. The stab position noted was observed to be approximately between the first and second mark using the leading edge surface as a reference point. Soot on the vertical stabilizer provided an indication of an impact position of about 8 degrees airplane nose up, based on the detent marks on the vertical stabilizer.

The horizontal stabilizer jackscrew was examined on the airplane through an access panel. The part and serial numbers were not visible from the access panel. The jackscrew did not exhibit any visible indication of impact or fire damage and appeared to be in good condition. The jackscrew was noted in the full aircraft nose down position, measured approximately 25 and 5/16 inches from the attachment nut to the end of the jackscrew. Witnesses at the wreckage site indicated that prior to visual examination of the horizontal stabilizer, heavy equipment removing cargo had altered the stabilizer position by grabbing and pulling the stabilizer control cables.

F. Trailing Edge Flaps

Two sets of triple-slotted trailing edge flaps, outboard and inboard, are normally operated by system A hydraulic pressure, but may be operated electrically using the alternate flap system. The flap control lever on the center control pedestal has eight detented positions at UP, 2°, 5°, 15°, 25°, 30°, and 40°, with gates located at the 2° and 25° detents. A bolt has been installed to prevent flap handle movements beyond the 30° position, since FedEx B727's have been certified for 30° landing flaps only.

The center aisle stand and flap handle track were located in the wreckage. No flap handle was recovered. No assessment of the position of the flap selector was possible.

The trailing edge flap jackscrews were identified and measured. The four left wing jackscrews were found intact on the wing. All four of the right wing trailing edge flap jackscrews were found in the debris field and identified. The screws appeared to be intact with minimal signs of impact damage. Each jackscrew was measured for engineering reference dimensions (A and B) used to determine the effective flap angle versus jackscrew position (see Table below).

	Left Wing	Right Wing
Outboard Flap		
Outboard Jackscrew		
A Dimension (in.)	30½	31
B Dimension (in.)	5	5
Inboard Jackscrew		
A Dimension (in.)	31	30⅝
B Dimension (in.)	5	5¼
Inboard Flap		
Outboard Jackscrew		
A Dimension (in.)	38⅞	39
B Dimension (in.)	5½	5
Inboard Jackscrew		
A Dimension	39⅜	37
B Dimension	4⅜	7

Table – Jackscrew Measurements

The A and B ball screw measurements were converted to effective flap positions based on tables supplied by the airplane manufacturer. Based on the tables, each measurement of the jackscrews was converted to effective trailing edge flap in the approximate 30° extended position.

G. Leading Edge Flaps

Leading edge flaps are normally actuated by system A hydraulic pressure and controlled by the outboard trailing edge flap position. When the extending trailing edge flaps reach 2°, two middle slats on each wing are extended. With the trailing edge flaps extended to 5°, all leading edge devices are full extended. When the trailing edge flaps are retracted, the sequence is reversed.

Observation and measurement of the leading edge flaps on the left wing indicated the leading edge flaps were in the approximately fully extended position. Each of the leading edge flaps exhibited slight impact damage. A segment of tree was found wedged between the inboard edge of the inboard (number 3) and the wing leading edge. The Boeing representative indicated that the leading edge flap actuators do not have an interlock mechanism to maintain position on loss of hydraulic pressure, therefore the flaps usually extend or droop after hydraulic pressure is removed from the flaps.

Two of the three right wing leading edge flap actuators were recovered in the debris field. All the recovered right wing leading edge flap actuators were found in the extended position.

H. Leading Edge Slats

Leading edge slats are normally actuated by system A hydraulic pressure and controlled by the outboard trailing edge flap position.

Observation and measurement of the left wing leading edge slats indicated the slats were in the fully extended position. The Boeing group representative indicated that the leading edge slat actuators incorporate a lockout mechanism that prevents the rod from retracting in the absence of hydraulic pressure. Substantial damage was noted on the left wing outboard leading edge slat, number 1. The surface was sheared through and bent back. The slat actuator rod was bent at an angle of approximately 45° based on visual inspection.

Three of the four right wing leading edge slat actuators were recovered in the debris field. All of the recovered right wing leading edge slat actuators were found in the extended position.

I. Spoilers

All spoilers on the left wing were observed in the retracted position. The spoilers did not exhibit visible indications of impact or fire damage. All spoilers and spoiler actuator were measured or observed in the retracted position.

All seven right wing spoilers were recovered in the debris field. All of the right wing spoiler actuators were found in the spoiler surface retracted position.

10. Fuel

A portion of the flight engineer's lower instrument panel, including the fuel system control panel and the fuel head control panel, was recovered from the wreckage. Due to fire damage to the panel, no assessment of indication of the switch position and gauges was possible.

The flight deck center aisle stand was recovered from the flight deck. The aisle stand was severely damaged by fire, with the aisle stand body completely incinerated. The number 1, 2, and 3 engine run/cutoff switches were found approximately one-half-inch below the high ignition detent. The number 1 and 2 engine throttles were found slightly forward of the flight idle position, and the number 3 engine throttle was found at approximately the flight idle position.

The lower portion of the center instrument panel was recovered from the wreckage. Included in the panel were the engine 1, 2, and 3 fuel flow gauges. Due to severe fire damage no assessment of indication of the gauges was possible.

11. Hydraulic Power

A portion of a flight engineer's hydraulic system panel was recovered from the wreckage. However, fire damage to the panel prevented assessment of the switch positions and hydraulic gauge indication.

The airplane's main and standby hydraulic system reservoirs and standby pump were located in the tail section of the airplane. The reservoirs appeared intact and did not exhibit visible fire damage.

12. Indicating/Recording Systems

Schematic drawings of the general flight deck instrument panels were provided by the airline and included in Attachment 5.

A. Captain's P1-1 Panel and Instrument Indication Assessment

The captain's P1-1 panel was not located in the wreckage. However, the captain's mach/airspeed indicator and radio magnetic indicator (RMI) were located. Due to fire damage no assessment of indication of the captain's RMI was accomplished.

The captain's electric mach/airspeed indicator, a Smiths Industries p/n 10-61818-151, s/n unknown, receives and displays information from the airplane's central air data computer (CADC).

The glass face from the instrument was removed and the instrument face and scale were destroyed by fire damage. All indications were made by comparison to a drawing of the instrument.

The airspeed pointer indicated approximately 118 knots. The V_{MO} pointer indicated approximately 360 knots. The airspeed cursor was found at an indication of about 154 knots. The airspeed indicator flag was evident in the digital airspeed readout window, the MACH flag was visible in the Mach window, and the V_{MO} flag was noted in the V_{MO} flag window. A photograph of the instrument's indication is included as Attachment 6-1.

B. Captain's P1-2 Panel and Instrument Indication Assessment

A portion of the P1-2 panel was recovered. The captain's instrument comparator, attitude display indicator and horizontal situation indicator were recovered. No assessment of indication was accomplished.

C. Captain's P1-3 Panel and Instrument Indication Assessment

A portion of the P1-3 panel was recovered. The captain's approach progress panel was not recovered. The captain's electric altimeter, radio altitude indicator, TCAS/VSI,

clock, and yaw damper indicator were recovered. The partial P1-3 panel was removed from the wreckage and sent to the NTSB Materials Laboratory in Washington, D.C. for teardown and assessment of indication.

1) Captain's Electric Altimeter

The captain's electric altimeter part and serial number were unreadable from fire damage; however, the airline indicated the installed instrument to be a Smiths Industries p/n 2055-01-1, s/n 291.

The instrument's glass face was removed. The cylinders for the digital altitude readout were melted; no estimate of digital altitude indication was possible. The altitude pointer indicated between 440 and 450 feet. Fire damage to the instrument made determination of the barometric reference pressure setting in inches of mercury impossible, but the indicated reference pressure setting was 1,019 millibars (calculated as approximately 30.09" of mercury). The altitude reference bug was not located. A photograph of the instrument face and indication is included as Attachment 6-2.

2) Captain's Radio Altitude Indicator

The captain's radio altimeter's part and serial number were unreadable from fire damage; however, the airline indicated the installed instrument to be a Collins p/n 522-4114-003, s/n 2777.

The instrument's glass face was removed. Based on a comparison with drawing of the instrument, the radio altitude needle indicated approximately 1,150' AGL. The minimum decision altitude bug was noted at approximately –20' AGL. The warning flag was visible. A photograph of the instrument's indication is included as Attachment 6-3.

3) Captain's Clock

The captain's clock's part and serial number were unreadable from fire damage. When the clock's glass face was removed, the clock indicated a time of approximately 10:20:00. The airline indicated that the captain's clock was typically set to coordinated universal time (UTC). Therefore, the indicated time was converted to 6:20 local time. A photograph of the clock's indication is included as Attachment 6-4.

4) Captain's Upper and Lower Rudder Position Indicator

The captain's upper and lower rudder position indicator's part and serial number were unreadable from fire damage; however, the airline indicated the installed instrument to be an Ametek p/n 260582, s/n not available.

When the instrument's glass face was removed, the left and right elevator pointers were not located. The upper and lower rudder pointers were located and both indicated a

position right of neutral. The lower rudder position was indicated at approximately the location of the right-hand tick mark of the three ticks found in the center of the upper and lower rudder scale. The upper rudder position was indicated just to the right of the lower rudder position. The upper rudder yaw damper flag was visible; the lower rudder yaw damper flag was not located. A photograph of the instrument's indication is included as Attachment 6-5.

5) Captain's TCAS/VSI

The captain's traffic alert and collision avoidance system (TCAS)/vertical speed indicator (VSI) contained a liquid crystal display; therefore indication assessment was not possible.

D. Captain's/First Officer's P2 Panel and Instrument Indication Assessment

A portion of the P2 center instrument panel was recovered. The partial panel included 10 indicators – the engine 1, 2, and 3 fuel flow gauges, the engine 1, 2, and 3 N2 gauges, the exhaust gas temperature (EGT) gauges, the engine 1, 2, and 3 N1 gauges, and one engine pressure ratio (EPR) gauge. The standby attitude indicator and one EPR gauge were recovered detached from the panel. No assessment of indication was accomplished for any center instrument panel gauge except the EPR gauge.

The EPR gauge's part and serial number were unreadable due to fire damage; therefore engine the EPR gauge represented was undetermined. However, the airline identified the installed EPR gauge for the left engine as a Honeywell p/n JG298A4, s/n F218, the EPR gauge for the center engine as a Smiths Industries p/n 2045-06-1, s/n not available, and the EPR gauge for the right engine as a Honeywell p/n JG298A4, s/n B17.

The EPR gauge glass face was missing when the gauge was located in the wreckage. No removal of the instrument face was necessary to read indications. All the instruments scale indications were destroyed by fire damage. Based on a comparison of the unit to photographs of similar gauges, the EPR pointer needle indicated approximately 1.9, while the EPR cursor indicated a value of about 2.0. A photograph of the gauge's indication is included as Attachment 6-6.

E. First Officer's P3-1 Panel and Instrument Indication Assessment

The first officer's P3-1 panel was not recovered. The first officer's radio magnetic indicator, automatic direction finder, pneumatic mach/airspeed indicator, and approach progress display panel were recovered. The first officer's pneumatic mach/airspeed indicator was sent to the NTSB's Materials Laboratory for teardown and indication assessment; however, no assessment of indication for the other P3-1 panel flight instruments was accomplished.

The first officer's pneumatic mach/airspeed indicator part and serial number were

destroyed by fire damage; however, the airline identified the installed instrument as Smiths Industries p/n WL606AMA9, s/n AJ760.

The mach/airspeed indicator's glass face was broken and darkened from fire and smoke damage. After the glass face was removed, the instrument's airspeed pointer indicated approximately 60 knots. The MACH flag was visible in the mach indicator window. The airspeed cursor was located at approximately 148 knots and the selector knob could not be rotated. The maximum operational airspeed (V_{MO}) pointer indicated about 185 knots. A photograph of the instrument's indication is included as Attachment 6-7.

F. First Officer's P3-2 Panel and Instrument Indication Assessment

The first officer's P3-2 panel was not recovered. The first officer's attitude display indicator, horizontal situation indicator, and comparator light panel were recovered. No assessment of indication was accomplished.

G. First Officer's P3-3 Panel and Instrument Indication Assessment

The first officer's P3-3 panel was not recovered. However, the first officer's pneumatic altimeter, radio altitude indicator, TCAS/VSI, and clock were recovered. The first officer's pneumatic altimeter and radio altitude indicator were sent to the NTSB's Materials Laboratory for teardown and indication assessment. No further indication assessment of the other P3-3 panel flight instruments was accomplished.

1) First Officer's Pneumatic Altimeter

The first officer's pneumatic altimeter's part and serial number were unreadable due to fire damage; however, the airline identified the installed instrument as Kollsman p/n A44488-10-008, s/n 233.

The altimeter's glass face was broken and darkened from fire and smoke damage. After the glass face was removed, the instrument face was observed as blistered from fire damage. The digital altitude readout indicated a value of 11,400 feet. The altitude pointer indicated 450 feet. The fire damage to the instrument made determination of the barometric reference pressure setting in millibars impossible, but the indicated reference pressure setting in inches mercury, read using a microscope, was approximately 30.10" with the hundredth indication between "0" and "1". A photograph of the instrument's indication is included as Attachment 6-8.

2) First Officer's Radio Altitude Indicator

The first officer's radio altitude indicator part and serial number were destroyed by fire damage; however, the airline identified the installed instrument as Collins part number (p/n) 522-4114-003, serial number (s/n) AJ760.

The radio altitude indicator's glass face was broken and darkened from fire and smoke damage. After the glass face was removed, the instrument needle indication was approximately 360 feet above ground level (AGL), the minimum decision bug was set at approximately –20 feet. The radio altitude scale was between –20 and +2,500 feet AGL. A portion of the warning flag was visible in the upper-right corner of the instrument. A photograph of the instrument's indication is included as Attachment 6-9.

H. Additional Flight Deck Instruments

Several loose gauges were found in the wreckage. Due to fire damage the identity of the gauges could not be determined. Also, due to fire damage no assessment of indication was possible for the indicators. A clock was found in the flight deck wreckage with an indication of 10:11:15.

The flight deck whiskey compass was located in the wreckage. The compass was partially melted by fire damage and was stuck. The compass indicated a heading of approximately 120 degrees.

13. Landing Gear

The landing gear handle was recovered in the flight deck wreckage. The handle was separated from the center instrument panel. The handle was severely damaged by fire. No assessment of handle position was possible.

Nose gear truck structure was found separated from the gear. The nose gear trunion was separated from the airplane and folded under the fuselage.

The left main landing structure was attached to the airplane and was an approximately fully extended position. Portions of the gear linkage to the fuselage were broken off the gear, including the linkage used to visually-verify the fully down and locked position of the gear. Therefore, a visual confirmation of gear position was not possible.

The right main landing gear structure was located in the main wreckage site, separated from the airplane. Portions of the right gear structure and gear doors were found in the wreckage path. No assessment of the position of the right main landing gear could be made.

14. Lights

The lower overhead lighting panel was located in the flight deck wreckage. The panel was severely burned and most of the switches were bent or broken, such that assessment of indication was not possible. However, the left and right outboard landing light switches appeared to be in the up or "off" position, while the left and right inboard landing light switches appeared to be in the down or "on" position. The taxi, navigation, and strobe light switches all appeared to be in the down or "on" position. No other flight

deck light control panels or switches were located in the airplane wreckage.

The left wingtip light structure was located, intact on the airplane. The left wing trailing edge "cornstalk" light was also located on the airplane. Portions of the right wingtip structure, including the strobe electronics box and cornstalk light, were noted in the debris field away from the main wreckage location.

The surface of the left outboard landing light on the number 1 leading edge flap was broken. The left inboard landing light was undamaged.

15. Oxygen

Portions of the flight crew oxygen masks and hoses were located in the wreckage. In addition, a fire-damaged flight crew oxygen bottle was found. No assessment of the items was possible due to fire damage. No flight deck indicators or panels relating to the oxygen system were located in the wreckage.

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Attachments

1. Schematic Drawings of Radio Altitude Transceiver and Antennas
2. Schematic Drawing of Barometric/Pitot Static System
3. FedEx Flight 1478 Cargo Weight and Distribution Paperwork
4. Schematic Drawings of Major Flight Control Surface Components
5. Flight Deck Panels Schematic Drawings
6. Flight Instrument Photographs