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

April 10, 2006

POWERPLANT GROUP CHAIRMAN'S FACTUAL REPORT

NTSB No: DCA-06-MA-009

A. ACCIDENT

Location:	Chicago Midway Airport, Chicago Illinois
Date:	December 8, 2005
Time:	1914 central standard time
Aircraft:	Southwest Airlines' Boeing 737-7H4, N471WN, flight No. 1248

B. POWERPLANTS GROUP

Group Chairman:	Jean-Pierre Scarfo National Transportation Safety Board Washington, D.C.
Member:	Leslie McVey CFM International Cincinnati, Ohio
Member:	Jeffrey Austin Federal Aviation Administration Indianapolis, Indiana
Member:	Mark Babb Southwest Airlines Dallas, Texas
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Member:	Floyd Houdashell Southwest Airlines SWAPA Phoenix, Arizona

C. SUMMARY

On December 8, 2005, 1914 Central Standard Time, Southwest Airlines flight 1248, a Boeing B-737-7H4 registered as N471WN, overran runway 31C at Chicago Midway Airport in Chicago, Illinois, during the landing rollout. The airplane departed the end of the runway, rolled through a blast fence, a perimeter fence, and onto a roadway. The airplane came to a stop after impacting two automobiles. Instrument meteorological conditions prevailed at the time. The airplane was substantially damaged. The flight was conducted under 14 CFR Part 121 and had departed from the Baltimore/Washington International Thurgood Marshall Airport, Maryland.

The Powerplant Group convened on December 9, 2005 to commence examination of the airplane and engine and completed its task on December 13, 2005. Examination of the engines revealed that both had sustained considerable fan blade damage but neither had a fan blade separation, exit holes, uncontainments, or signs of fire indicative of a catastrophic engine failure. The tips of the fan blade airfoils leading edges were curled in the direction opposite rotation. All the stage 4 LPT blades were intact, remained installed in the disk, and none exhibited any trailing edge damage. No metallic debris or oil was noted on any of the stage 4 LPT blades or in the LPT case, the turbine frame, or the exhaust nozzle. The engine examination did not reveal any pre-impact hardware damage or anomalies to suggest there were any problems associated with the engine prior to impacting the blast and perimeter fencing.

All the thrust reverser cascades were heavily imbedded with snow, wood, red metallic and red rubber debris and being this same debris was found resting against the front face of the blocker doors consistent with the reversers deployed when the airplane crashed through the blast fence and the airport perimeter fence. A continuity check of the hydraulic lines that run from the thrust reverser control valve modules to their respective thrust reverser actuators was performed for both the Nos. 1 and 2 engine thrust reverser systems. No breaches or leaks in the stow and deploy hydraulic lines were noted for the No. 1 engine. Continuity of the thrust reverser hydraulic lines for the No. 2 thrust reverser system could not be verified due to the impact damage sustained on the leading edge of the right wing that severed the stow and deploy lines in that area. However, no breaches or leaks in the stow and deploy hydraulic lines were noted from the thrust reverser control module to the area of the wing leading edge impact damage and from the wing leading edge impact damage area to the No. 2 engine. Examination of the thrust reverser hardware did not reveal any pre-impact damage or anomalies to suggest that there were any thrust reverser problems prior to impacting the blast and perimeter fencing.

D. DETAILS OF THE INVESTIGATION

1.0 ENGINE INFORMATION

1.1 ENGINE HISTORY AND MAINTENANCE RECORDS

The accident airplane was equipped with two CFM International (CFMI) CFM56-7B24 engines. Both engines were new when the airplane was delivered to Southwest Airlines in June 2004 and neither engine has been removed from the airplane since it was delivered. Therefore, neither engine has been overhauled nor had a maintenance shop visit. The left-hand engine (No. 1), serial number (SN) 890899, and the right-hand engine (No. 2), SN 890900, both accumulated 5,273 hours time since new (TSN) and 2,901 cycles since new (CSN) at the time of the accident.

Review of Southwest Airlines Maintenance form SA-M663 from October 8, 2005 to the date of the accident revealed no discrepancies or deferrals relating to the thrust reverser. No discrepancies were noted on either engine - only normal engine servicing. The Federal Aviation Administration (FAA) conducted a search of thrust reverser Airworthiness Directives (AD) for this engine and airplane combination and none were found to be applicable.

1.2 ENGINE DESCRIPTION

The CFM56-7B24 engine is a high bypass, dual rotor, axial flow turbofan engine that features a titanium wide-chord single stage fan integrated with a three-stage low pressure compressor (LPC - booster) driven by a four-stage low pressure turbine (LPT); a nine-stage high pressure compressor (HPC) driven by a single-stage high pressure turbine (HPT); and an annular combustion chamber. The CFM56-7B24 turbofan has a maximum standard day sea level thrust rating of 24,000 pounds. The CFM56 turbofan engine is a product of CFM International (CFMI), and the company is jointly owned by General Electric Aircraft Engines (GEAE) of the United States and Société Nationale d'Etude et de Construction de Moteurs d'Aviation (SNECMA) of France.

All directional references to front and rear, right and left, top and bottom, and clockwise and counterclockwise are made aft looking forward (ALF). The direction of rotation of the engine is clockwise. All numbering starts with the No. 1 position at the 12:00 o'clock location and progresses sequentially clockwise ALF.

1.3 THRUST REVERSER DESCRIPTION

The thrust reverser (TR) system changes the direction of the fan air exhaust to help create reverse thrust. Fan air exhaust goes radially outwards and forward when the TRs are deployed. The flight crew uses reverse thrust to slow the airplane after landing or during a rejected takeoff. Each engine has its own TR (TR 1 refers to the TR for the left engine and TR 2 refers to the TR for the right engine).

The TR system for the Boeing 737 airplane is comprised of three subsystems: TR, control, and indicating. The TR subsystem is the physical structure that re-directs the fan exhaust and each TR has a left- and right-hand half. Each TR half primarily consists of a translating sleeve that moves aft when deployed for reverse thrust, six (6) sets of cascades, five (5) blocker doors, three (3) hydraulic actuators and two (2) sync shafts (rotary flex shafts). The control subsystem consists of the TR lever, the micro-switch packs in the

pedestal that provides a signal to deploy or stow, an Engine Accessory Unit (EAU) and Electronic Engine Control (EEC) to coordinate the TR translating sleeve movement and proximity sensors that provide positioning reports for the translating sleeve. The indicating subsystem is comprised of messages on the CDS and lights on the engine panel to indicate to the flight crew the current status and position of the TR.

1.3.1 TR System

The two translating sleeves on each TR work at the same time; however, the sleeves are independent from each other. The translating sleeves are stowed when they are in the full forward position and deployed when they are in the full aft position. When the translating sleeve moves aft during TR deployment, the blocker doors are moved into the fan duct changing the direction of the fan air exhaust, and the cascades, which are stationary, control the direction of the fan air exhaust. Three hydraulic actuators that extend during deployment and retract during the stow sequence move each translating sleeve to its commanded position. Of the three actuators, one is a locking actuator that must be unlocked for the other actuators on that same half to operate. This locking actuator has a feedback mechanism that operates a linear variable differential transformer that supplies translating sleeve position data to the indicating system. To ensure that the hydraulics actuators extend and retract at the same speed, two rotary flex sync shafts are used.

1.3.2 Control System

The TR control system lets the TR deploy when the airplane is less than 10 feet (3 meters) from the ground. A DEPLOY signal is given when the TR lever is raised and a STOW signal is given when the TR lever is lowered. The TR lever operates three switches, “arm”, “stow”, and “sync lock” all located in the auto-throttle switch packs below the flight compartment aisle stand which are necessary to send a DEPLOY or STOW signal to the TR control valve module. Each TR lever operates a set of those three switches.

The “arm” switch supplies electrical power to the arm solenoid in the TR control valve module. The TR control valve module controls hydraulic actuators to deploy or stow each TR. There are two TR control valve modules on the airplane, one for each TR, both located in the main gear wheel well. The “stow” switch supplies power to the EAU stow logic circuits. The EAU has the electrical circuits necessary for stow operation and uses two TR proximity sensors for each TR sleeve for control. The EAU also interfaces with the TR indicating system to control the reverser light located on the engine panel in the cockpit. The EAU also uses the input from the sleeve proximity sensors for auto-restow logic. The “sync lock” switch supplies power to the TR sync lock circuits. A sync lock is connected to the bottom hydraulic actuator on each TR half and is energized to unlock them so that the sync shafts can turn to deploy or stow the TR half. Without electrical power, the sync locks are in the locked position, thus the sync shafts can’t turn and the TR hydraulic actuators will not operate. The sync locks prevent operation of the hydraulic actuators when there is no TR deploy signal.

Each TR half has a stow and lock proximity sensor that supplies a signal to the EAU and each sensor has two output levels – stow or not stowed and locked or unlocked depending on the sensor in question. The EAU supplies excitation to the each sensor and sees a large change in output when the sensor’s target is CLOSED (near). For the lock sensor, the target moves close (near) to the proximity sensor when the hydraulic actuator unlocks during a TR operation and stays in that position until the sleeve comes back to the stow position and the hydraulic actuator locks. For the stow sensor, the target moves close (near) to the proximity sensor when the TR sleeves moves out of the stow position during TR deployment and stays in the near position until the sleeve comes back to the stow position.

1.3.3 Indicating System

The TR indicating system supplies translating sleeve position data to the common display system (CDS) in the cockpit. A REV message appears just above the engine N1 indictors on the CDS for each engine and changes colors depending on the TR position - amber when one or both translating sleeves are between 10° and 90° of the travel to the deploy position and green when both are more than 90° to the travel to the deploy position. The EEC and the display electronics unit (DEU) contain the logic necessary to operate the REV message. Amber REVERSER fault lights on the engine panel (aft overhead panel) come on when any of the TR control systems components do not operate correctly. The EAU contains the logic necessary to identify TR control system component failures and controls the REVERSER fault lights. A master caution also comes on with the REVERSER light.

2.0 ON-SITE INVESTIGATION

2.1 GENERAL OBSERVATION

The airplane was found at the south side of intersection between 55th Street (east/west direction) and Central Avenue (north/south direction), directly past the end of runway 31C off the airport property (**Photos 1 and 2**). The airplane was found on its nose, both main landing gears, and both engines. Both engines remained attached to their pylon and the pylons remained attached to the airplane.

PHOTOS 1 AND 2: AC FINAL RESTING POSITION

The wooden blast fence at the end of the runway 31C had damage consistent with the size and shape of the engine inlets (**Photos 3 and 4**). The in-situ observations were taken at the location where the airplane came to rest prior to its removal to a hanger on the Midway Airport property where additional examination and documentation occurred.

PHOTOS 3 AND 4: DAMAGED WOODEN BLAST FENCE AT THE DEPARTURE END OF 31C

2.2 ENGINE NO. 1 – LEFT HAND

2.2.1 Engine No. 1 Cowlings (Inlet & Fan) and Thrust Reverser Examination In-Situ

Approximately 50% of the nose cowl outer skin was ripped from the inlet cowl from the 6:00 to 12:00 o'clock position. At the 6:00 o'clock position, an airport perimeter fence pole was found imbedded in the inlet cowl (**Photo 5**). The left-hand fan cowl appears relatively intact except for some leading edge impact damage from the 6:00 to 7:00 o'clock position and in the vicinity of the center latch. The right-hand side fan cowl appears intact except for leading edge impact damage from the 4:00 to 6:00 o'clock position.

PHOTO 5: FAN SECTION AND INLET OF NO. 1 ENGINE

The left-hand translating sleeve was deployed approximately 19.25-inches at the 9:00 o'clock position in-line with the non-locking actuator and 19.75-inches at the 11:30 o'clock position in-line with a locking actuator (**Photo 6**). All the left-hand blocker doors appeared intact, present, and fully deployed. There were no visible gaps between blocker doors (**Photo 7**). Debris consistent with wood chips and fragments was observed on the aft face of the blocker doors[1], on the translating sleeve inner skin (flow path), the inner duct, and the core exhaust nozzle (**Photo 7**). All the cascades remained installed and were intact. Snow, wood, red metallic, and red rubber debris was noted heavily imbedded within the cascade airflow openings and against the front face of the blocker doors[2]. The left-hand translating sleeve appeared to be mostly still engaged with its lower main track; however, wood was found embedded within the sleeve at approximately the 7:00 o'clock position that locally dislodged the sleeve from the track.

PHOTO 6: LEFT-HAND SIDE OF NO. 1 ENGINE

PHOTO 7: CLOSED BLOCKERS DOORS

[1] The aft face of the blocker door is the surface viewed ALF through the fan exhaust when the blocker door is deployed (CLOSED).
[2] The wood material was consistent with the material of the jet blast fence located at the departure end of the runway 31C and the red metallic debris was consistent with the material and color of the localizer antenna also located at the departure end of the runway 31C. The front face of the blocker door is the surface viewed forward looking aft through the fan exhaust when the blocker door is deployed (CLOSED).

The right-hand translating sleeve appeared to be essentially in the stowed position (**Photo 8**). The translating sleeve was partially seated against the fan cowl at the 5:00 o'clock position; however, a noticeable gap existed between the translating sleeve and the fan cowl that progressively got larger from the 5:00 to 1:00 o'clock position consistent with a canted sleeve. The maximum gap measured 1.5-inches at the 1:00 o'clock position in-line with the locking actuator. All the right-hand blocker doors appeared intact, present and fully stowed. Debris consistent with wood chips and fragments was also observed pinned between the blocker doors and inner skin of the translating sleeve. This same wood debris was observed in the translating sleeve inner skin, the inner duct, and the core exhaust nozzle.

PHOTO 8: RIGHT-HAND TR - STOWED

2.2.2 Engine No. 1 Examination In-Situ

All the fan blades remained installed in the fan disk and leading edges of all the airfoils exhibited impact damage, tears, and missing material. The tips of the fan blade airfoils leading edges were curled in the direction opposite rotation. Circumferential rub, in-plane with the fan blade normal running position, was observed in the fan case. The spinner was intact, remained attached to the fan disk, and exhibited scrape marks. All the stage 4 LPT blades were intact, remained installed in the disk, and none exhibited any trailing edge damage. No metallic debris or oil was noted on any of the stage 4 LPT blades or in the LPT case, the turbine frame, or the exhaust nozzle.

2.2.3 Engine No. 1 Fan Cowl and Thrust Reverser Examination in the Hanger

The fan cowls were secure and locked. Three latches are used to secure both fan cowls halves with the latch handles and mechanisms located on the left-hand fan cowl and the latch keepers located on the right-hand fan cowl. All three latches remained attached to the left-hand fan cowl. The forward most and the rearward most latches appeared undamaged while the center latch was heavily damaged and distorted, but intact (**Photo 9**). All three latch keepers were intact and undamaged.

PHOTO 9: DAMAGED CENTER LATCH

With the fan cowls open, the TR system was exposed for examination. All six translating sleeve actuators appeared still in place and secure and their push/pulls rods appeared visually to be straight and undamaged. Table 1 provides the part numbers and serial numbers for all six No. 1 engine thrust reverser translating sleeve actuators. No hydraulic leaks were observed coming from any of the actuators or from either the stow and deploy hydraulic tubes. The inlet aft bulkhead and thrust reverser torque box were bent aft from approximately the 5:00 to 7:00 o'clock position.

TABLE: 1 NO. 1 ENGINE THRUST REVERSER TRANSLATING SLEEVE ACTUATORS

Left-Hand Actuators			Right-Hand Actuators		
Position	PN	SN (DOM)	Position	PN	SN (DOM)
7:00 o'clock	315A2800-1	12388 (2Q04)	1:00 o'clock	315A2801-1	6339 (1Q04)
9:00 o'clock	315A2800-1	12389 (2Q04)	3:00 o'clock	315A2800-1	12218 (1Q04)
11:00 o'clock	315A2801-1	6339 (2Q04)	5:00 o'clock	315A2800-1	12220 (1Q04)

The TR manual unlock levers (located at the 11:00 and 1:00 o'clock positions), which also serve as targets for the TR sleeve lock proximity sensors, were found in the unstowed position (near position) covering the sensor. The TR sleeve stow proximity sensors, located at the 9:00 and 3:00 o'clock positions, were covered by their respective targets.

The right-hand translating sleeve was manually driven open and no binding was noted. Snow, wood, red metallic, and red rubber debris was noted imbedded within the cascade airflow openings and against the front face of the blocker doors similar to what was observed on the left-hand side (**Photo 10**). With both translating sleeves open, the lower main tracks and liners for the left- and right-hand TRs were examined and they appeared to be in good condition. The left-hand translating sleeve was not in the fully deployed position and using the synchronizing lock actuator, the sleeve was manually moved aft approximately 1.5 to 2.0-inches from its as-found position. When an attempt was made to manually stow the translating sleeve (move it forward), the sleeve moved forward approximately 1.5 to 2.0 inches (back to its as-found position), became bound, and would not move any farther forward due damage to the lower part of the sleeve.

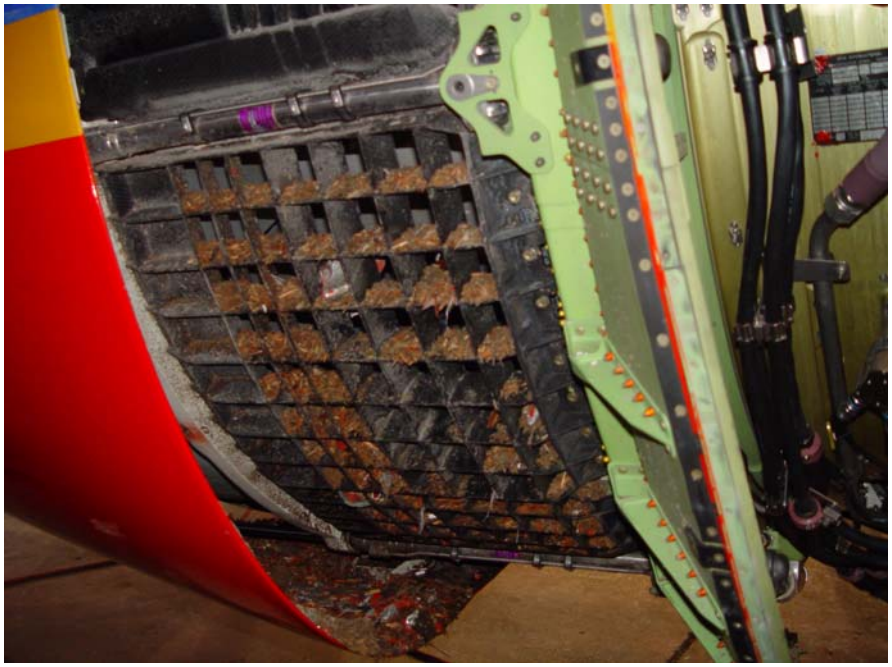

PHOTO 10: DEBRIS IN CASCADES

Examination of the left-hand TR revealed no damage to the blocker doors and their associated hardware; however, on the right-hand side TR, blocker door in the No. 5 position was damaged (See Figure 1). The No. 5 blocker door exhibited a "V"-shaped crack coming from the drag link hinge. The drag link itself was bowed and distorted. All the cascades for both the right- and left-hand sides were intact, present, undamaged and, were verified to be in the correct orientation, position, and part number per the parts manual.

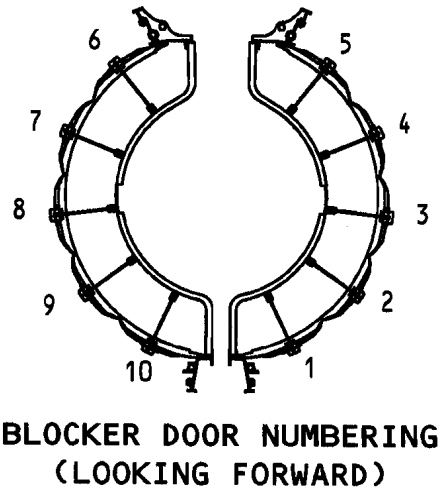

FIGURE 1: BLOCKER DOOR LOCATIONS

2.2.4 Engine No. 1 Examination in the Hanger

Examination of the engine revealed no exit holes, uncontainments, or signs of fire. The fan case inner contour exhibited many impact marks spanning from the forward flange to the struts of the basic fan frame structure. The fan case was bulged outwards at the 2:30 o'clock position and within the bulge, the case was cracked (**Photo 11**).

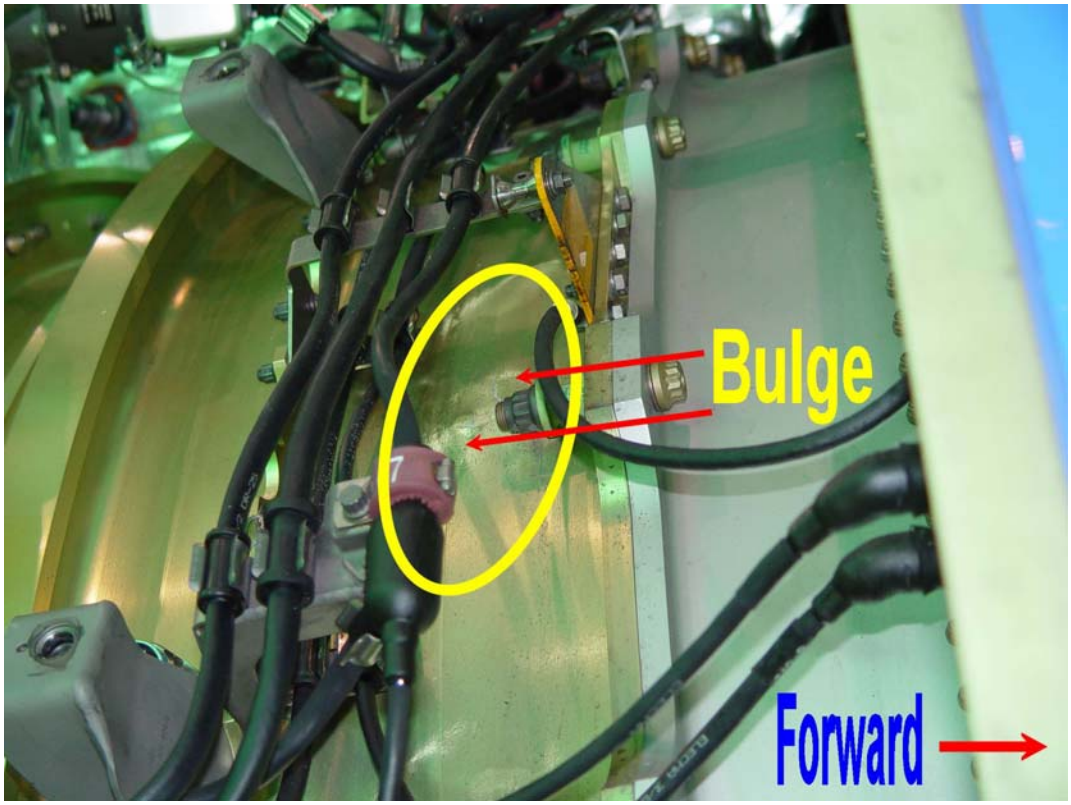

PHOTO 11: BULGE IN FAN CASE

All the accessories remained attached to the fan frame assembly with no major visible damage noted except that both ignition exciter boxes exhibited impact damage and their mount brackets were distorted. The accessory gearbox (AGB) was scuffed and had some minor gouging at the 7:30 o'clock position; however, no cracks or holes were noted. The AGB oil scavenge tube was distorted but no oil leakage was noted. The anti-icing valve position-indicating arrow was pointed to the CLOSED position.

The Electronic Engine Control (EEC), P/N 1853M33P06, S/N LMDN9120 was intact and undamaged. The EEC was removed and shipped to the British Aerospace (BAE) Systems Service Center for download of the non-volatile memory (NVM) for fault examination. See section *3.0 ELECTRONIC ENGINE CONTROL DOWNLOAD* for details.

2.3 ENGINE NO. 2 – RIGHT HAND

2.3.1 Engine No. 2 Cowlings (Inlet & Fan) and Thrust Reverser Examination In-Situ

The nose cowl appeared intact and exhibited impact damage, buckling, and tearing with the majority of the damage at the 6:00 o'clock position. The left-hand inlet cowl did not exhibit any significant damage while the right-hand inlet cowl skin was torn and exhibited material loss. Impact damage, tears, and missing material were observed on both the left- and right-hand fan cowls; however, the damage to the right-hand side was far more extensive than what was observed on the left-hand side.

The left-hand translating sleeve was deployed approximately 20.625-inches at the 9:00 o'clock in-line with the non-locking actuator and 21.50-inches at the 11:30 o'clock position in-line with the locking actuator (**Photo 12**). All the left-hand blocker doors appeared intact, present and deployed but not fully. Gaps were visible between blocker doors. Traces of wood debris were noted from the 6:00 to 8:00 o'clock positions on the cowl exhaust nozzle and the translating sleeve inner skin. All the left-hand cascades were intact and present. Snow, wood, red metallic, and red rubber debris were noted to be heavily imbedded within the cascade airflow openings and against the front face of the blocker doors (**Photo 13**).

PHOTO 12: LEFT-HAND TR DEPLOYED

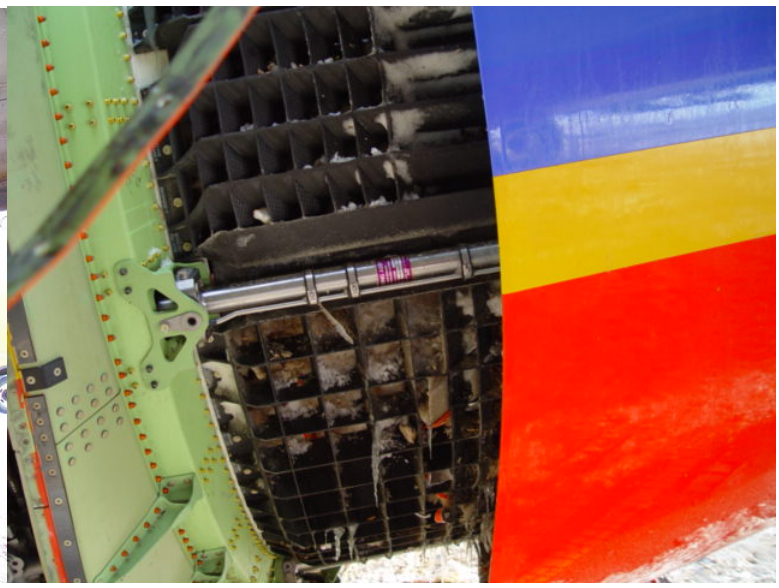

PHOTO 13: DEBRIS IN THE CASCADES

The right-hand translating sleeve was deployed approximately 20.187-inches at the 1:00 o'clock position in-line with the locking actuator. At the 3:00 o'clock position, an approximately 45 x 45-inch triangular section of the translating sleeve was missing (**Photos 14 & 17**). The edges of the remaining skin piece were torn and exhibited no signs of fire or thermal distress. All the right-hand blocker doors appeared intact, present and deployed but not fully. Gaps were visible between blocker doors and the gaps were greater than those observed on the left-hand side. Debris consistent with wood chips and fragments was noted on the aft face of the blocker doors from the 3:00 to 6:00 o'clock positions and on the translating sleeve inner skin and core exhaust nozzle from the 12:00 to 1:00 o'clock positions. The amount of wood debris found on the right-hand side was significantly more than what was observed on the left-hand side. Several pieces of the right-hand cascades were broken and missing with cascade fragments found in the snow in the vicinity of the right engine. Snow, wood, red metallic, and red rubber debris were noted to be heavily imbedded within the cascade airflow openings and against the front face of the blocker doors. The right-hand torque box separated from the fan frame resulting in the TR separating from the engine (**Photo 15**). Both translating sleeves appeared to be still engaged with their respective lower main tracks.

PHOTO 14: RIGHT HAND-COWL & TR DAMAGE

PHOTO 15: TORQUE BOX SEPERATED FRM FRAN FRAME

2.3.2 Engine No. 2 Examination In-Situ

The damage observed on the No. 2 engine was similar to the type of damage observed on the No. 1 engine previously documented in section *2.2.2 Engine No. 1 Examination In-Situ*. All the fan blades remained installed in the fan disk and leading edges of all the airfoils exhibited impact damage, tears, and missing material (**Photo 16**). The tips of the airfoil leading edges were curled in the direction opposite rotation. Circumferential rub, in-plane with the fan blade normal running position, was observed in the fan case. The spinner was intact, remained attached to the fan disk, and exhibited scrape marks. All the stage 4 LPT blades were intact, remained installed in the disk, and none exhibited any trailing edge damage. No metallic debris or oil was noted on any of the stage 4 LPT blades or in the LPT case, the turbine frame, or the exhaust nozzle.

PHOTO 16: FAN SECTION AND INLET OF NO. 2 ENGINE

2.3.3 Engine No. 2 Fan Cowl and Thrust Reverser Examination in the Hanger

The fan cowl latching for the No. 2 engine is the same as on the No. 1 engine with the latch handles and mechanisms located on the left-hand cowl and the latch keepers on the right-hand cowl. The only fan cowl latch that remained intact, secured, and locked was the rearmost latch. The center latch keeper remained attached to the right-hand cowl but its corresponding latch handle was missing. The forward most latch assembly (latch handle and receptacle) was missing.

With the fan cowls open, the TR system was exposed for examination. The thrust reverser was distorted/pushed rearwards approximately 5-inches at the 3:00 o'clock position but remained flush at 12:00 and 6:00 o'clock positions. All three actuators for the left-hand translating sleeve appeared still in place and secure and their push/pulls rods appeared to be straight and undamaged. No hydraulic leaks were observed coming from any of the left-hand actuators. All three actuators for the right-hand translating sleeve appeared still in place and the push/pull rods for the actuators at the 1:00 and 5:00 o'clock position appeared to be straight and undamaged while the push/pull rod for the actuator at the 3:00 o'clock position was buckled forming a "V" shape and was cracked (**Photo 17**). No

PHOTO 17: BENT ACTUATOR PUSH/PULL ROD

hydraulic leaks were observed coming from any of the actuators but hydraulic fluid was noted on the inner skin of the translating sleeve in the vicinity of the cracked actuator push/pull rod at the 3:00 o'clock position. Table 2 provides the part numbers and serial numbers for all six No. 1 engine thrust reverser translating sleeve actuators.

TABLE: 2 NO. 2 ENGINE THRUST REVERSER TRANSLATING SLEEVE ACTUATORS

Left-Hand Actuators			Right-Hand Actuators		
Position	PN	SN (DOM)	Position	PN	SN (DOM)
7:00 o'clock	315A2800-1	12238 (1Q04)	1:00 o'clock	315A2801-1	6343 (2Q04)
9:00 o'clock	315A2800-1	12239 (1Q04)	3:00 o'clock	315A2800-1	12569 (2Q04)
11:00 o'clock	315A2801-1	6195 (1Q04)	5:00 o'clock	315A2800-1	12568 (2Q04)

The TR manual unlock levers, located at the 11:00 and 1:00 o'clock positions, which also serve as a targets for the TR sleeve lock proximity sensors, were found in the unstowed position (near position) covering the lock sensor. The TR sleeve stow proximity sensors, located at the 9:00 and 3:00 o'clock positions, were covered by their respective targets.

Both the left- and right-hand translating sleeve track appeared to be in good condition. Similar to the No. 1 engine, no blocker door damage was observed on the left-hand TR; however, on the right-hand TR, No. 5 blocker door exhibited a "V" shaped crack coming from the drag link hinge (**Photo 18**). All the cascades for the left- and right-hand TRs were in the correct orientation and position and all the part numbers were verified to be correct in accordance with the maintenance manual except for assembly 320 on the right-hand TR. A section of the cascade assembly 320 was missing where the part number is normally stamped; therefore, the part number could not be verified.

PHOTO 18: CRACKED BLOCKER DOOR

2.3.4 Engine No. 2 Examination in the Hanger

Examination of the engine revealed no exit holes, uncontainments, or signs of fire. The fan case exhibited no holes or uncontainments, but many impact marks spanning from the forward flange to the struts of the basic fan frame structure with the most significant damage listed as follows:

- Rib B2 exhibited a gouge at the 6:00 o'clock position
- Ribs B4 and B5 were bent aft at the 5:30 to 7:00 o'clock position and cracked at the rib-to-case skin transition radius

- Ribs B6 and B7 exhibited gouges from 3:00 to 3:30 o'clock position

The oil tank was missing from its normal installation position on the lower right-hand side of the fan case; however, a large fragment of the tank was found lodged in the right-hand translating sleeve. The hydraulic pump was separated from the AGB and was recovered on-site. The AGB itself was heavily damaged and large sections of the case and its contents from the 6:00 to 7:00 o'clock position were missing. The lower AGB mount bracket (6:00 o'clock position) was bent back and a fragment of the AGB still remained attached. The lubrication unit - which consists of the four positive displacement pumps (three scavenge and one supply), supply filter, check valve, bypass valve, pressure relief valve, and three magnetic chip detectors (MCDs) - and the oil cooler were pushed up and back against the fan case. Most of the tubing and wiring located between the 5:00 and 7:00 o'clock positions was damaged. Both ignition exciter boxes exhibited impact damage and the mounting brackets were distorted. The N1 speed sensor was pulled from its fan frame mount and was bent aft. The vibration sensors mounted on the fan case at the 3:00 o'clock position exhibited impact damage. The integrated drive generator (IDG) housing was cracked and had a 1.5 x 2.5-inch diameter hole. The anti-ice valve position-indicating arrow was pointed to the CLOSED position.

The EEC, P/N 1853M33P06, S/N LMDN9114 was intact but damaged. The forward lower corner was smashed, the lower panel was open exposing the plug inner connections, and some of the cooling fins were pushed over and flattened (**Photo 19**). The EEC was removed and shipped to the BAE Systems Service Center for download of the NVM for fault examination. See section *3.0 ELECTRONIC ENGINE CONTROL DOWNLOAD* for details.

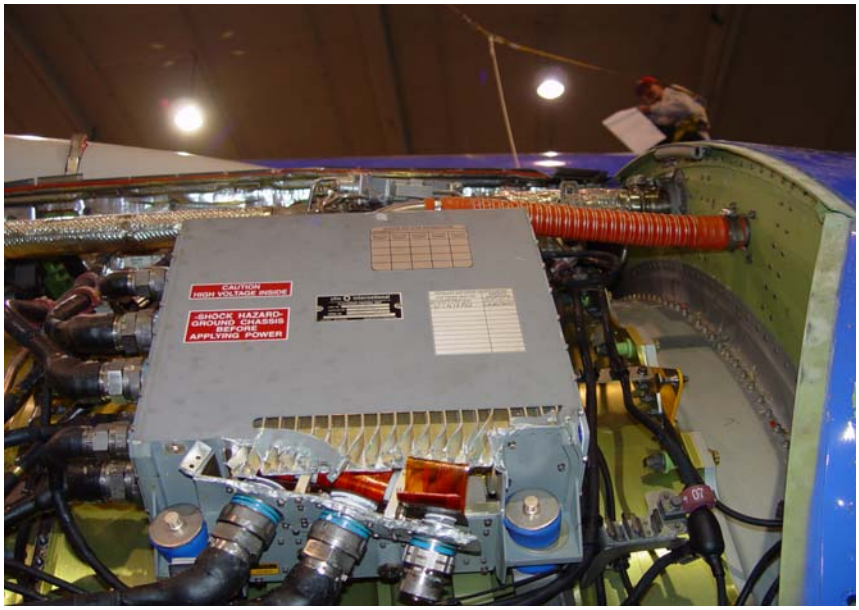

PHOTO 19: DAMAGED EEC FROM NO. 2 ENGINE

2.4 THRUST RESERVER CONTROL SYSTEM - HYDRAULICS

The TR control valve modules control hydraulic power to the TR hydraulic actuators and each one has a handle that is used to deactivate the TR for maintenance. The TR control valve modules are located in the main landing gear wheel well on the keel beam with No. 1 engine valve located on the left-hand side (referred to as the TR 1 control module) and the No. 2 engine valve located on the right-hand side (referred to as the TR 2 control module). The manual isolation valve handle for both the TR 1 and TR2 control valves were found safety wired in the OPEN position. The pointer on the hydraulic oil transmitter for the system "A" tank was between the empty and refill tick marks while the pointer for the system "B" was at zero. The pointer for the hydraulic accumulator was at 1,000 psi.

A continuity check of the hydraulic lines that run from the TR control valve modules in the main landing gear wheel well, along the fuselage through the leading edge of the wing to the TR actuators located on

the engine, was performed for each system. No breaches or leaks in any of the hydraulic lines that run from TR 1 control module to the No. 1 engine were noted. All the hydraulic line fittings still had the Boeing torque strip/witness mark intact. The hydraulic lines were not continuous from the TR 2 control module to the No. 2 engine. Both the stow and deploy hydraulic lines were fractured in the area where the right wing sustained impact damage (**Photos 19 and 20**). No breaches or leaks in any of the hydraulic lines were noted from the TR 2 control module to the area of the wing leading edge impact damage and from the wing leading edge impact damage area to the No. 2 engine.

PHOTO 19: RIGHT WING LEADING DAMAGE

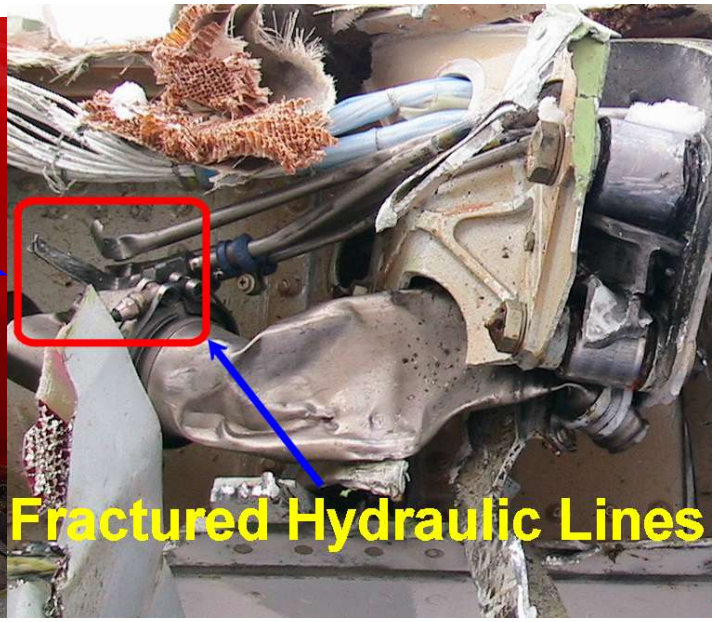

PHOTO 20: FRACTURED TR HYDRAULIC LINES

2.5 COCKPIT INSTRUMENT DOCUMENTATION

Table 3 provides pertinent engine, TR system, and aircraft switch positions. No engine related circuit breakers were popped.

TABLE 3: COCKPIT SWITCH POSITIONS

Nomenclature	Switch Position	Nomenclature	Switch Position
Throttles (Both)	IDLE	Electric Driven Pump	ON
Reverser Levers (Both)	STOWED	Fire Handles (All three)	PULLED & ROTATED LEFT
Engine Anti- Icing	OFF	Wing Anti-Icing	OFF
High Pressure Fuel Shutoff Valve (Start Levers)	CUTOFF	Engine Start Switches (Both)	LT CONTINUOUS
Speed Brake	DOWN & ARMED	Hydraulic Pumps – System "A"	ENG 1 - ON ELEC 1 - ON
Hydraulic Pumps – System "B"	ENG 2 - ON ELEC 2 - ON		

3.0 ELECTRONIC ENGINE CONTROL DOWNLOAD

The Powerplant group assembled at the BAE Systems Service Center in Fort Wayne, Indiana on December 14, 2005 to download the EECs for both the Nos. 1 (SN LMDN9120) and 2 (SN LMDN9114) engines. The NTSB was unable to participate in the EEC examination; however, the FAA, along with party members from Southwest Airlines and General Electric observed the download that was accomplished by BAE. According to BAE Systems, they have no record of either of these EEC units having been sent back to BAE for any maintenance, repair, or testing. Both EEC units were originally PN 1853M33P06 with software PN 1853M78P24 version 7BP (7B5A) installed and was later upgraded to PN 1853M78P25 version 7BQF2 (7B5F)[3]. The upgrade was performed on July 25, 2005.

Data was retrieved directly from EEC SN LMDN9120. No "No Dispatch" faults were recorded; however, a total of three "Long Time Dispatch" faults were recorded - 1 on channel "A" and 2 on channel "B". Table 4 provides a list of the faults and pertinent data recorded at that time. The exact time of each fault is not known because there is no time stamp associated with each discrete fault; however, parameters from the "Independent Snapshot Data" file associated with each recorded fault can be correlated with FDR data to determine sequencing and timing. All the faults occurred during the accident flight leg; however, due to resolution differences between the EEC and FDR recorded data, fault timing between the two can only be correlated to the nearest minute.

TABLE 4: EEC SN LMDN9120 FAULT AND INDEPENDENT SNAPSHOT DATA

	Fault 1 – Channel "A"	Fault 2 – Channel "B"	Fault 3 – Channel "B"
Description	ADIRU1/2 TAT data frm DEU1/2 missing	ADIRU1/2 TAT data frm DEU1/2 missing	T12 signal is out of range
Independent Snapshot Data			
Selected Fan Rotational Speed	1403.0000 RPM	1407.0000 RPM	1406.0000 RPM
Selected Core Speed	10116 RPM	10184 RPM	10112 RPM
Selected TRA Position	41.0000°	41.0234°	40.9766°
Fault History	Fault occurred in current leg	Fault occurred in current leg	Fault occurred in current leg

According to the "Control Learning Data" output file for EEC SN LMDN9120, the No. 1 engine had accumulated approximately 1,565 hours, 785 cycles, and 744 flight legs from the time the software upgrade occurred to time of the accident and this data was the same for both channels "A" and "B".[4]

Data was not retrieved directly from EEC SN LMDN9114 due to damage to the three connectors (J9, J10, and J11) and to the unit itself. Instead, the NVM data file was retrieved by moving the digital processing modules from the accident EEC into a slave unit. A total of 36 faults were recorded. The faults are as follows: 1) 18 were "No Dispatch" faults – 9 each on channels "A" and "B", 2) 2 were "Short Time Dispatch Faults" – 1 each on channels "A" and "B", 3) 12 were "Long Time Dispatch Faults" – 2 on channel "A" and 10 on channel "B" and 4) 4 "Economic Dispatch Faults" – 2 each on channels "A" and "B". The list of faults was too numerous to create a Table similar to that created for SN LMDN9120 listing all the faults.

[3] Software versions 7BP and 7BQF2 represents the certificated release of that software while 7B5A and 7B5F designates the software build number from which those certificated releases were created..

[4] The engine times, cycles, flight legs, and other parameters can be reset back to zero when new software is installed; thus they may not match the total engine hours and cycles of the engine.

Instead only pertinent faults are listed in Table 5. For a complete lists of faults of both EECs, see BAE report (Attachment 1).

TABLE 5: EEC SN LMDN9114 FAULT AND INDEPENDENT SNAPSHOT DATA		
CHANNEL "A"		
	Fault	Fault
Fault Type	No Dispatch	Short Time Dispatch
Description	ENG ident signal out of range	Alternator voltage to EEC out of range
Independent Snapshot Data		
Selected Fan Rotational Speed	6215.0000 RPM	6215.0000 RPM
Selected Core Speed	17524 RPM	17524 RPM
Selected TRA Position	36.2344°	36.2266°
Fault History	Fault occurred in ground run	Fault occurred in ground run
CHANNEL "B"		
	Fault	Fault
Fault Type	No Dispatch	Long Time Dispatch
Description	ENG ident signal out of range	Internal EEC Fault
Independent Snapshot Data		
Selected Fan Rotational Speed	6215.0000 RPM	6215.0000 RPM
Selected Core Speed	17524 RPM	17524 RPM
Selected TRA Position	36.2344°	26.344°
Fault History	Fault occurred in ground run	Fault occurred in ground run

Examination of the "Control Learning Data" output from EEC SN LMD9114 revealed that according to channel "A", the No. 2 engine had accumulated 1,559 hours, 791 cycles, and 743 flight legs; however, according to channel "B" for that same EEC, the engine accumulated 1,561 hours, 792 cycles, and 744 flight legs. The EEC "Control Learning Data" for a particular flight leg is initially stored in random access memory (RAM) until the core speed spools down through 30%, consistent with the termination of that flight, at which time the data is stored in NVM. If a power interruption occurs, which appears to be the case based on the Short Term Fault on channel "A" (Alternator voltage to EEC out of range), prior to the core speed reaching 30%, the "Control Learning Data" is lost and not transferred into NVM. Instead, the "Control Learning Data" observed would be from the previous flight. According to BAE, this is what appears to have happened and is consistent with the discrepancy in times, cycles, and flight legs between channels "A" and "B" for the EEC installed on the No. 2 engine.

No throttle system or thrust reverser faults were recorded on either EEC unit. Furthermore, according to BAE Systems, there were no recorded faults prior to accident flight leg.

Jean-Pierre Scarfo
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National Transportation Safety Board

ATTACHMENTS

1. BAE Systems Report on SWA 1248, dated December 14, 2005