



## Uncontained Disk Failure in Right Engine of DC-9 During Initial Takeoff Run Results in Rejected Takeoff and Aircraft Evacuation

*U.S. National Transportation Safety Board investigators determined that the Turkish maintenance station that had last inspected the compressor disk had overlooked a detectable flaw that caused the disk to fragment.*

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*FSF Editorial Staff*

The crew of the ValuJet Airlines [McDonnell] Douglas DC-9-32 was cleared for takeoff on Runway 27R at the William B. Hartsfield Atlanta International Airport, Atlanta, Georgia, U.S. As the aircraft began its takeoff roll, a high-pressure compressor (HPC) disk in the right engine ruptured, flinging shrapnel into the fuselage and the right-engine main fuel line, which was followed by a cabin fire.

The flight crew rejected the takeoff, stopped the aircraft on the runway and ordered an evacuation of the aircraft. All of the crew members and passengers successfully exited the aircraft. A flight attendant received serious puncture wounds from shrapnel and burn injuries. Another flight attendant and five passengers received minor injuries during the evacuation. The two pilots, the third flight attendant and 52 passengers were not injured in the June 8, 1995, accident. The aircraft was destroyed.

The U.S. National Transportation Safety Board (NTSB) determined "that the probable cause of the accident was the failure of Turk Hava Yollari [THY, A.O. (Turkish Airlines), which had overhauled the failed engine before that engine and other equipment were bought by ValuJet] maintenance and inspection personnel to perform a proper inspection of a seventh-stage HPC disk, thus allowing [a] detectable crack to grow to a length at which the disk ruptured, under normal

operating conditions, propelling engine fragments into the fuselage; the fragments severed the right-engine main fuel line, which resulted in a fire that rapidly engulfed the cabin area.

"The lack of an adequate record-keeping system and the failure to use 'process sheets' to document the step-by-step overhaul/inspection procedures contributed to the failure to detect the crack and, thus, to the accident."

The accident aircraft, operated by ValuJet Airlines, was on a regularly scheduled passenger flight from Atlanta to Miami, Florida, U.S., under U.S. Federal Aviation Regulations (FARs) Part 121. Flight 597 (the accident flight) departed the gate and taxied for takeoff at 1855 local time, with five crew members and 57 passengers onboard. The flight was cleared for takeoff at 1908.

"As Flight 597 began its takeoff roll, a 'loud bang' was heard by the airplane occupants and [U.S. Federal Aviation Administration (FAA)] air traffic control [ATC] personnel," the report said. "Passengers reported looking rearward in the direction of the sound and observing flames and fuel around the aft flight attendant."

The flight crew of another aircraft that was holding on the runway for takeoff behind the accident flight transmitted to the



Photo: AP Wide World Photos

*All crew members and passengers successfully evacuated ValuJet Flight 597, a DC-9 that was destroyed by fire after an engine failure during takeoff roll.*

ValuJet crew that the right engine was on fire. This report prompted the captain of Flight 597 to reject the takeoff. At the same time, the right-engine fire-warning light illuminated in the cockpit of the accident aircraft, the report said.

“Shrapnel from the right engine penetrated the fuselage and the right-engine main fuel line, and a cabin fire erupted,” the report said. The aircraft came to a stop on the runway centerline, approximately 457 meters (1,500 feet) west of the approach end of the runway.

After the engines were shut down, the captain attempted to use the aircraft’s public address (PA) system to communicate with the passengers but was unable to do so, the report said. The captain then selected emergency electrical power, which restored power to the PA system, and issued an order to evacuate the aircraft.

The flight attendants in the front of the aircraft “opened the forward passenger boarding door and the service door exits, and the airplane was evacuated,” the report said. “The flight attendant at the service door exit stated that when the door was opened, the cabin filled with smoke from about waist level up to the ceiling.”

The Atlanta Fire Department (located at the airport) was notified of the accident by a supervisor in the FAA ATC tower, and the first fire-fighting units arrived on the scene at 1911, the report said. “When the Atlanta Fire Department units arrived, all occupants had evacuated the airplane,” the report said. “The two flight attendants in the forward section of the airplane and the first officer reported that shortly after they exited the airplane following the passengers, the fire-fighting vehicles arrived on the scene.”

When the fire fighters arrived, they saw “fire near the No. 2 (right) engine and heavy smoke emanating from all exits,” the report said. “Fire-fighting personnel reported that the fire was spreading rapidly through the airplane from rear to front. The fire was brought under control about 1922 and extinguished about 1925,” the report said.

## **Flight Attendant Seriously Injured**

The flight attendant seated in the aft flight-attendant jumpseat “sustained second degree burns on her legs and two puncture wounds above and below the inside of her left knee,” the report said. “Unidentified pieces of the airplane debris were removed from the flight attendant’s leg by medical personnel.”

In addition, “five passengers sustained minor lacerations and contusions during the evacuation,” the report said. “They were treated at the scene, transported to local medical facilities for [treatment of] hyperventilation and smoke inhalation and released the same day.”

The fuselage of the accident aircraft was destroyed by fire, “which gutted the interior, burned through the roof of the forward cabin area of the airplane and consumed most of the cabin overhead,” the report said.

The accident occurred at dusk, in visual meteorological conditions (VMC), the report said.

Investigators reviewed the wreckage of the accident aircraft. “Debris from the right engine was found on the runway, ... about [30.5 meters (100 feet)] west of the runway threshold to

the stopped airplane,” the report said. “Additional engine debris was found in the grass areas on either side of the runway. The overwing exit hatch from the right side of passenger seat row 14 was found on the runway, about [366 meters (1,200 feet)] west of the runway threshold,” the report said.

The right engine was found attached to the pylon structure. “A circumferential tear of the engine nacelle encompassed the upper and lower nacelle doors from approximately the 9 o’clock position clockwise to the 6 o’clock position,” the report said. “The circumferential opening was approximately [35.5 centimeters (14 inches)] wide and about [170 centimeters (67 inches)] aft of the engine inlet flange. The circumferential tear of the right-engine nacelle was aligned with the rotational plane of the seventh-stage HPC disk.”

The report continued: “The torn edges were ragged and curled outboard, away from the center of the engine. The forward edges of the hole were burned, with the paint blistered and charred. The nacelle was heat-damaged from about the 1 [o’clock] to 6 o’clock position, to about [38 centimeters (15 inches)] forward of the circumferential opening. The nacelle lower half was covered with soot aft of the circumferential opening.”

Investigators were able to recover only two pieces of the fractured seventh-stage HPC disk (Figure 1), and a substantial portion of the disk was not recovered, the report said. “One piece, about half of the disk, was found resting on the accessory gear box, visible through the circumferential tear in the cowling,” the report said. “The seventh-stage compressor blades retained in the disk were bent opposite the direction of rotation.”

The left engine was examined and had “a dent and a [0.63-centimeter (one-fourth-inch)-diameter] puncture at about the 4 o’clock position in line with a series of holes through the fuselage,” the report said. “Inspection of the engine inlet, inlet guide vanes, fan and fourth-stage blades did not reveal any damage. There was no fire damage.”

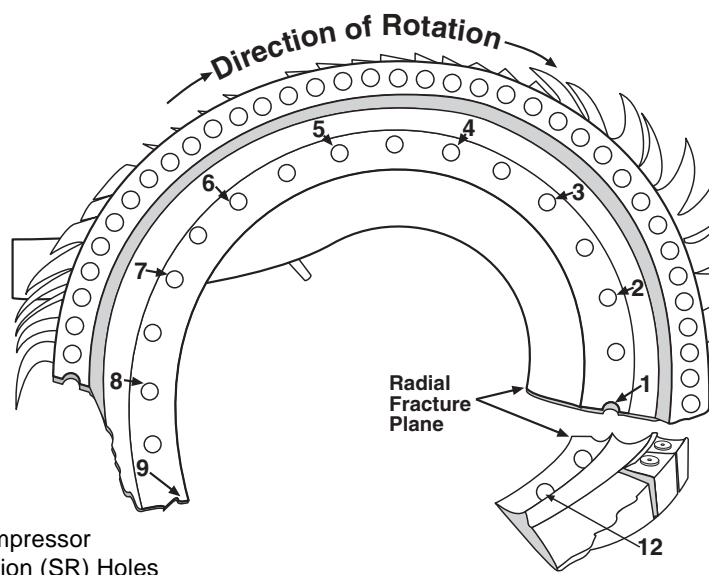
When the fuselage was examined, investigators found several punctures “in the fuselage above and below the right-engine pylon,” the report said. “The largest puncture was adjacent to the right-engine main fuel line. A [15.2-centimeter (six-inch)] section of the fuel line was severed where it passed through the aft lavatory sidewall, about [30.5 centimeters (one foot)] above the cabin floor. The lavatory door had an approximate [30.5-centimeter]-diameter puncture hole adjacent to the forward door frame.”

The report continued: “The left side of the fuselage under the engine pylon had a puncture hole with outward-bent edges, consistent with a projectile penetrating the left side of the fuselage from inside to outside. A rope was used to establish that the hole in the right side of the fuselage, the hole in the lavatory door, damage to the galley cooler and frame, the exit hole in the left side of the fuselage and the dent in the left-engine cowling were all aligned.”

## Cabin Fire Damage Was Extensive

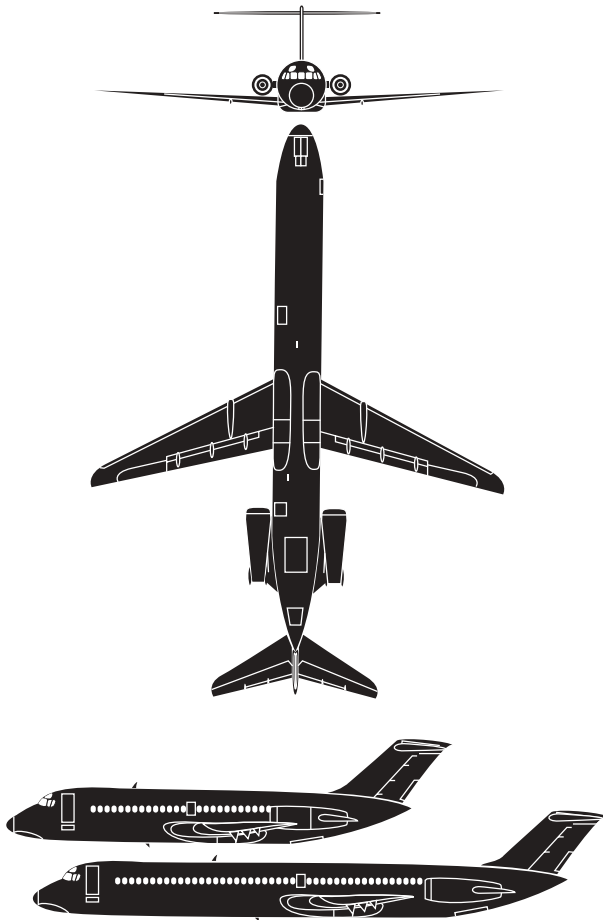
Investigators reviewed the fire damage and found that the damage “inside the aft lavatory was less severe than the fire damage elsewhere in the passenger cabin,” the report said. “The cabin-

**View Looking Forward of the Recovered Portion of the Seventh-stage HPC Disk From the Right Engine of ValuJet Flight 597**



HPC = High-pressure Compressor  
Numbers = Stress-reduction (SR) Holes  
Source: U.S. National Transportation Safety Board

**Figure 1**



### McDonnell Douglas DC-9

The twin-turbofan short/medium range McDonnell Douglas DC-9 was first flown in 1965 and has been stretched to increase passenger seating in several subsequent versions. It has a maximum takeoff weight of 44,450 kilograms (98,000 pounds) and a maximum cruising speed at 25,000 feet (7,620 meters) of 491 knots (909 kilometers per hour). The Series 30 has a range of 1,288 nautical miles (2,388 kilometers) at an altitude of 30,000 feet (9,150 meters) with reserves for a 200-nautical mile (370-kilometer) flight to an alternate and a 60-minute hold at 10,000 feet (3,050 meters).

Source: *Jane's All the World's Aircraft*

floor support beam at the forward edge of the lavatory, which extended from sidewall to sidewall, was nearly burned through at the center. The section of cabin floor surrounding the beam was partially melted and burned. The cargo-bay liner beneath the aft lavatory was charred on the top and sides. Wire bundles and conduits between the cabin floor and the cargo-bay liner in the same area as the damaged floor beam were more severely burned than in adjacent areas.”

The injured flight attendant’s jumpseat was located “immediately aft of the center-aisle section that was nearly burned through,” the report said. “The jumpseat was also just

aft of the path made by the rope used to establish the relationship between the right-side fuselage hole and the dent in the left-engine cowling.”

Further examination of the fuselage revealed that “the top of the cabin, above the cabin windows, was consumed by fire from the second window rearward to about the 15th window,” the report said. “There was severe interior fire damage to the entire passenger cabin, with sooting and blackening of the interior of the cockpit. The seat fabric, carpet and cabin interior material were nearly consumed by the fire.”

The evacuation slides and emergency exits were examined. “The evacuation slides at both the forward floor-level exits were found deployed and inflated,” the report said. “All overwing exit hatches were absent. One overwing exit hatch was found on the runway along the debris trail. The passenger seated in 14E stated that he opened the right overwing exit hatch located by his seat and threw it from the airplane. The passenger seated in 20C stated that when he moved to the right-side overwing exits, another passenger removed one of the exit hatches and handed it to him, and he laid it in the adjacent seat.”

The report continued: “A third hatch was found adjacent to the aft window frame forward of row 16, on the left side of the airplane. It was not determined how the left overwing exit hatches were removed. Soot trails on the exterior of the aircraft extended up and aft from the overwing exits and the forward doors. Photographs taken by a passenger and provided to the [NTSB] showed flames visible at the overwing exit and smoke at the forward and overwing exits. The tailcone, aft of the rear pressure bulkhead, was in place and not burned.”

When investigators examined the cockpit, they found the emergency power switch in the “on” position, “and the emergency-lighting switch was in the ‘armed’ position,” the report said. “The left- and right-engine fire handles were in the aft, or activated, position. Both fuel-shutoff valves were in the closed position and both fire-suppression bottles had been discharged into the right engine.”

The background and maintenance history of the accident aircraft were reviewed. ValuJet Airlines purchased the accident aircraft from the Douglas Aircraft Co. (of which McDonnell Douglas is one division) and put the aircraft into service in 1994, the report said. The aircraft, which had previously been operated by Delta Air Lines, was powered by two Pratt & Whitney JT8D-9A turbofan engines.

The right engine on the accident aircraft was installed in March 1995. ValuJet had purchased the engine from THY, “in a large equipment purchase on Oct. 3, 1994, that included a total of 23 engines,” the report said. The sale included nine aircraft, five spare engines (one of which was the accident engine) and 4,400 spare parts. “THY is a Turkish domestic and international airline that also operates an airframe and engine-repair station.”

The right-engine seventh-stage HPC disk on the accident aircraft had been overhauled in 1991, the report said.

“In September 1994,” the report said, “ValuJet contracted with Avionics and Aircraft Systems Engineering Services Inc. (AAS), to provide ... on-site management of the aircraft delivery program ... . One of the original consultants, who was a vice president at AAS, became the primary manager of the purchase and importation process.”

The report noted that the primary manager had previously been, at various times, responsible for writing FAA-approved maintenance programs, developing and managing a FARs Part 121 aircraft acceptance program, directing a passenger-to-freighter aircraft-configuration conversion program, directing a cockpit/avionics standardization program, developing several large-aircraft FAA-approved supplemental type certificates and developing guidelines for the DC-9 structural inspection document program.

### **ValuJet Established Preacceptance Inspection Procedures**

“Before ValuJet’s acceptance of any engine or aircraft, each was subjected to a ground inspection that included the following [among others]:

- “Verification that all records and manuals were being delivered, and that they were complete and current;
- “A borescope inspection of all mounted and spare engines;
- “Verification that any structural damage had been repaired in full compliance with the aircraft DC-9 structural repair manual or approved McDonnell Douglas data;
- “Verification of aircraft airworthiness, and currency of U.S. FAA airworthiness directives (ADs) on all aircraft; [and,]
- “Verification that all mounted engines were ‘serviceable’ in accordance with [Pratt & Whitney] engine manuals.”

The report said that the aircraft and the engines powering them for ferrying the aircraft to the United States were subjected to a flight test program. “According to the consultant, the test flights, which were conducted by a ValuJet-contracted pilot, the AAS representative and a THY employee, were performed in accordance with the Douglas DC-9-32 *Used Production Flight Procedures Manual*.”

The AAS consultant evaluated the THY and maintenance scheduling and record-keeping system. “As part of this process,” the report said, “AAS reviewed all entries in the aircraft maintenance log of each airplane for the last two years, or since the last ‘D’ check, whichever came last. AAS also reviewed the records of all mounted engines, spare engines and major components for the last two years.

“During this review, any entries that could not be accurately determined were translated into English. In addition, other applicable records, such as FAA Forms 337, *Major Repair or Alteration*, AD and engine-disk status records, and certain shop records associated with the repair of spare parts, were translated into English.”

The accident engine, which was in line service when the AAS consultant arrived in Turkey, was removed from the airplane so that another engine intended for the ValuJet purchase could be tested operationally, the report said. The accident engine thus became one of the five “spare” engines.

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“According to the sales agreement between ValuJet and THY, all spare engines were to be certified as serviceable by an FAA-certified [FARs] Part 145 repair station before acceptance by ValuJet,” the report said. “ValuJet and THY agreed that the spare engines would be certified as serviceable by the THY repair station and then shipped to the United States with ‘serviceable tags.’” The report observed that serviceable tags are “a commonly used method for repair stations to attach a written maintenance release containing the information specified in [FARs] Part 43.9 to an aviation product to show that it is approved for return to service.”

According to the consultant who had arranged the sale and supervised the transfer of the airplanes and engines, THY placed serviceable tags on each spare engine, including the accident engine, the report said. “Entries on the tag for [the accident engine] indicated that it had been removed from an aircraft so that another engine could be installed and that [the engine] had been preserved for up to 90 days. ...

“According to the technical control director of THY’s repair station engine shop, THY intended that the statement of serviceability and release for return to service on the ‘serviceable tag’ apply to more than just the work listed on the tag (in the case of [the accident engine], removed from aircraft and preserved), and represented a ‘full’ statement of serviceability.”

The report expressed concern about ambiguity regarding the meaning of serviceable tags. Noting that “[the FARs] state that the signature on a maintenance record entry constitutes

approval for return to service only for the work performed,” the NTSB said that serviceable tags as used by the maintenance industry “vary considerably in format, and are sometimes relied upon as assurance of overall airworthiness. However, there appears to be no clear regulatory basis for such an assurance.”

The report added that serviceable tags should be “in a prescribed format (perhaps in the format of FAA Form 8130-3) and that when there is a change of ownership, and certainly upon importation, the approval for return to service [should] attest to the overall airworthiness of the part. [FAA Form 8130-3, *Airworthiness Approval Tag*, is used for “export approval, identification and conformity determinations of products and parts thereof from production approval holders. The form may also serve as an indication of approval for return to service for an FAA-approved repair station, or the holder of an air carrier operating certificate issued under (FARs) Parts 121, 127 or 135 with a continuous airworthiness maintenance program.”] The tag should reflect that a complete and thorough review of records, including ‘process sheets’ of the last overhaul, has taken place. In the absence of such records, an overhaul of the part should be required when there is a change in ownership.”

The report commented: “Although foreign repair stations are not subject to the same record-keeping requirements as [U.S.] domestic repair stations, the [NTSB] recognizes that most repair stations will voluntarily keep adequate records of work done and believes that the records available in this case [concerning THY’s inspection] met the minimum standards in existence at this time and were adequate for the consultant to conclude that the record-keeping system was valid.”

The report concluded: “Foreign repair stations should be subject to at least the same record-keeping requirements as domestic repair stations and ... the FAA should revise [FARs] Part 145 to require Subpart C foreign repair stations to adhere to the same record-keeping requirements of [FARs] Part 145.61.”

Nevertheless, the NTSB recognized that “even if THY had been subject to the same record-keeping requirements as domestic repair stations, it still would not have been required to keep records of the 1991 disk overhauls because the engine was installed on a non-U.S. (Turkish)–registered aircraft,” the report said.

## **Crack Found To Have Existed at Last Overhaul**

A metallurgical examination of the failed right-engine seventh-stage HPC disk revealed fatigue cracking in the vicinity of one of the disk’s stress-reduction (SR) holes. “Although the fracture

was heavily damaged, analysis of fatigue striation measurements ... indicated that a crack of about 12 millimeters (approximately one-half inch) existed in the disk at the last reported overhaul in 1991 ... . Thus, the [NTSB] concludes that a detectable crack existed ... when the disk was overhauled by THY in 1991, and [was] therefore detectable by FMPI [fluorescent magnetic particle inspection] or MPI [magnetic particle inspection].”

[MPI is a method of nondestructive testing to detect cracks in ferromagnetic materials such as iron and steel. The part under inspection is magnetized, and a liquid containing ferromagnetic particles in suspension is applied. The particles align themselves with the magnetic lines of flux on the surface of the part, forming a pattern. If a flaw is present on or near the surface of the material, the flaw will create a disruption of the pattern, or “indication.”

[FMPI is similar to MPI except that the ferromagnetic particles are also treated so as to luminesce under ultraviolet (black-light) inspection.]

The report added that “a 12-millimeter crack extending the depth of [the SR hole] and extending to the front and rear faces of the disk would have a probability of detection of 100 percent when inspected with either FMPI or MPI, according to the current Nondestructive Testing Information Analysis Center (NTIAC) *Nondestructive Evaluation Capabilities Data Book*.” [NTIAC is a U.S. government–funded information center.]

The metallurgical examination found, in addition to the fatigue crack, corrosion pits as deep as 0.08 centimeter (0.003 inch) that had been plated over with nickel-cadmium. “... The plating over of the pits indicates that they existed in the disk during the

overhaul inspection by THY in 1991, as that would have been the last time before the accident that the disk would have been off the engine,” the report said.

Investigators attempted to determine why the defective disk had not been properly inspected. They discovered that Pratt & Whitney engineering personnel had conducted a review of the THY maintenance shop for JT8D engines in 1991 — the year that the defective disk had been overhauled — and that Pratt & Whitney’s review report included the following findings and recommendations:

- “[THY] shop personnel are experienced and know the procedures for cleaning, stripping, plating and other repairs; however, new personnel sometimes enter the shop, and procedures are sometimes revised. Because the engine manual is written in English and presents a generic view of each procedure, [THY] should prepare process sheets that 1) describe the specific processes and repair procedures in Turkish, 2) describe actual shop

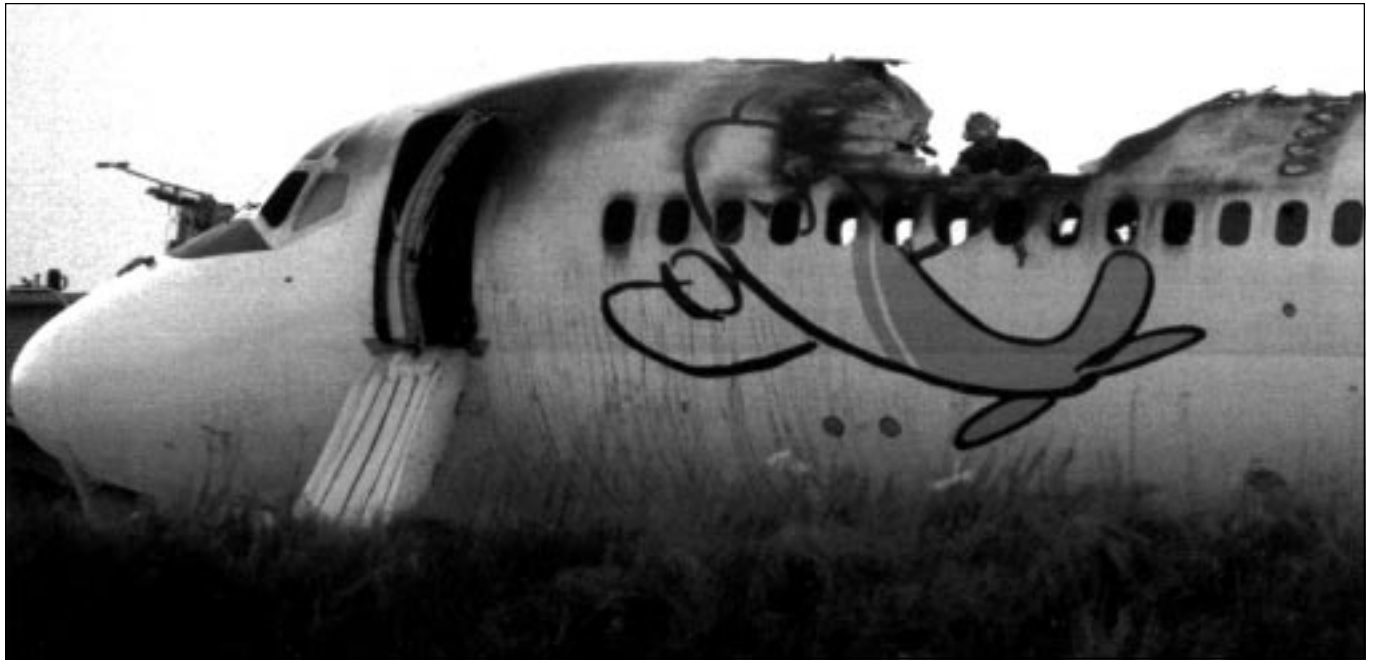


Photo: AP Wide World Photos

*The NTSB said that passengers did not follow prescribed evacuation procedures, but noted that the 57 persons aboard ValuJet Flight 597 had evacuated the aircraft by the time fire trucks reached the burning DC-9.*

equipment used at [THY] and 3) require shop personnel to sign each significant step of the procedure as that procedure is completed. Process sheets will help avoid many repair problems and will confirm that the complete, up-to-date procedure has been accomplished”; and,

- “The job card that routes the parts through FPI [fluorescent penetrant inspection] and FMPI does not specify the process or have a sign-off line for the inspectors to see that the work has been done. The only indication that the parts have been FPI inspected is a green wire attached to the parts. Several parts were found with green wires attached without any evidence of background fluorescence that is typical of parts that have been processed through the FPI line.”

[In FPI, a fluid that has good capillary action and that will fluoresce under ultraviolet light is applied to a part by spraying or soaking. The fluid seeps into any defect on the surface, which becomes visible when exposed to black light. FPI has a disadvantage and an advantage compared with magnetic techniques. Unlike FMPI or MPI, FPI will not show faults hidden below the surface; on the other hand, it can be used on aluminum or plastic, which are materials that cannot be magnetized.]

Pratt & Whitney recommended that the work cards used in the THY maintenance facility include “a sign-off line for the inspector, to permit the inspection process to be verified and the inspector for that part to be identified.”

“From this evidence,” the report said, “the [NTSB] concludes that the THY repair station was not using detailed

documentation to provide step-by-step guidance at the time of the 1991 overhaul and inspection of the seventh-stage disk.”

The report also said that “the 1991 [Pratt & Whitney] shop audit noted that THY’s FPI/FMPI inspectors were trained by one another, and recommended that THY develop a formal training program or send the inspectors to a nondestructive testing school to become qualified and that they be retested every one [year] to two years to ensure that they maintained their practical knowledge and theory.”

During its investigation, the NTSB interviewed the current director of the THY overhaul facility. “In response to the [NTSB’s] inquiry about whether THY’s repair facility had documented each step of the inspection and overhaul process,” the report said, “[the director] provided the [NTSB], as a sample, a small card (slightly larger than a [7.6-centimeter by 12.7-centimeter (three-inch by five-inch)] card) that had been used during the overhaul of a disk in 1995. The card had part-identification and operation data on one side, and handwritten notes about the repairs that had been done on the other side.

“The card listed repairs for removing and replacing the nickel-cadmium plating; however, it did not list [FMPI], which is a required inspection during disk overhaul, according to the [Pratt & Whitney] JT8D engine manual ... . The type of card displayed by the director of THY’s overhaul shop was not found in any engine record package for the failed engine.”

“It is unclear what type of inspection THY performed [in July 1991 on the accident-engine HPC disk], based on conflicting

statements by the director of THY's overhaul shop," the report said. "In a meeting with [NTSB] officials, he claimed that an MPI inspection was performed." In a June 1996 letter to the NTSB, the THY overhaul facility director wrote that an FMPI inspection had been performed.

The facility director also wrote that "it was necessary, in July 1991, to inspect for and remove surface corrosion pits from within the SR holes only if their depth was over 0.003 inch, based on the fact that the [Pratt & Whitney] engine manual did not list SR holes as a critical inspection area and 'it did not even show them in [the manual] until subject section of the manual was revised after June 1995.'"

The NTSB therefore examined how the Pratt & Whitney engine manual had addressed the inspection of the holes in the HPC disk. The report acknowledged that the manual's figure of the seventh-stage disk showed only 12 "tie-rod holes" and failed to show the adjacent 12 SR holes. Nevertheless, the report said, "The 24 holes on an actual disk are placed so close together that it is virtually impossible to inspect tie-rod holes without noticing the SR holes. ...

"The [NTSB] concludes that although the [Pratt & Whitney] engine manual could have presented this information in a way that would have made it clearer that the SR holes in the seventh-stage disk had to be inspected and could not contain any damage, the lack of clarity was not a contributing factor in the failure of the disk because the manual did clearly state that no damage was permissible in or near any hole." [The report said that the Pratt & Whitney engine manual required repair of any surface damage in, or within (0.03 centimeter [0.125 inch]) from, the edge of a hole.]

More important, the report said, "A properly performed inspection should have detected a crack estimated to be one-half inch long at the time of the THY overhaul in 1991. During an MPI, the entire disk is magnetized, and magnetic particles are applied to the disk. The SR holes would inescapably be included in this type of inspection because of their proximity to the tie-rod holes, and the one-half-inch crack would have been readily visible, not only inside the SR hole, but along the surface of the disk.

"During an FMPI inspection, the entire disk is not only magnetized, but also covered in a solution containing fluorescent iron particles that would further highlight any defects. Accordingly, the [NTSB] concludes that THY did not perform a proper inspection ... . Had the THY repair station accomplished a proper inspection ... , the crack would probably have been detected, the part rejected, and consequently, the accident [might] have been avoided."

During the investigation, "the [NTSB] received conflicting interpretations of THY's authority to overhaul JT8D engines," the report said. The FAA informed the NTSB that "THY did not have JT8D engine overhaul authority from 1986-1994." THY maintained that it did have FAA approval to overhaul JT8D and other engines during those years, the report said.

Investigators reviewed THY's FAA-approved operations specifications and found them in conflict with the FAA's position, the report said. "The [NTSB] is concerned that confusion about the extent of the authority of other repair stations may exist," the report said.

## FAA Review of Repair Station Operations Specifications Urged

The report concluded: "The [NTSB] believes that the FAA should review the Air Agency Certificates and Repair Station Operations Specifications of all repair stations and ensure that language in the operations specifications clearly indicates the extent of the repair stations' authority."

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Investigators found that during the predeparture preparations for the accident flight, "the flight crew noted that the [traffic-alert and collision avoidance (TCAS)]-system fail light remained illuminated," the report said. "The minimum equipment list for the accident aircraft indicated that the TCAS was not required for flight, and at the time of the accident, this discrepancy could be left uncorrected for up to 10 days."

The accident aircraft was equipped with both a cockpit voice recorder (CVR) and a digital flight data recorder (DFDR), the report said. The DFDR was an 11-parameter recorder, although two of the channels were not recording properly. Nevertheless, an excellent recording was obtained from the DFDR, the report said.

The NTSB definitions of recording quality are as follows: "A 'poor' recording is one in which a transcription is nearly impossible given that a large portion of the recording is unintelligible; a 'fair' recording is one in which a transcription is possible, but the recording is difficult to understand; a 'good' recording is one in which few words are unintelligible; and an 'excellent' recording is very clear and easily transcribed."

The CVR had separate channels for the cockpit area microphone, the pilot audio panel and the interphone/PA system. The CVR sustained no apparent interior heat or impact damage; nevertheless, a recording of only fair quality was obtained during the investigation, the report said. "The cockpit-area microphone-channel recording contained background



noise that nearly obliterated the pilots' voices and made them difficult to understand," the report said.

The report noted that if the accident aircraft had been equipped with a boom microphone ("hot mic") for each flight crew member, the quality of the CVR recording would have been much improved, the report said. "Given the numerous benefits of 'hot mics' and the slight cost of these installations, the [NTSB] believes that the FAA should require all airplanes currently required to be installed with a CVR to be retrofitted within two years with a CVR 'hot mic,'" the report said.

The background and qualifications of the flight crew were reviewed. The captain, 45, held a U.S. airline transport pilot (ATP) certificate, with an airplane multi-engine land rating, and DC-9, Boeing 737 and Learjet type ratings, the report said. He had 9,500 total flying hours, with about 3,500 hours in the DC-9 and 2,500 hours as a DC-9 captain. He also held a commercial certificate for airplane single-engine land and was a certificated flight instructor with airplane multi-engine and instrument airplane ratings. He held an FAA first-class medical certificate with no restrictions, the report said.

The captain was hired by ValuJet Airlines in 1993, as a captain on the DC-9, the report said. He had about 11 years previous experience with Eastern Airlines as a DC-9 captain and first officer, a Boeing 727 first officer and a Lockheed Martin L-1011 second officer. The captain was also a designated pilot examiner for Boeing 737 airplane type ratings.

In reviewing the captain's activities, the report said that he "reported for duty on the day of the accident at 1332, following three days off duty."

The first officer, 43, held a U.S. ATP certificate with airplane single-engine and multi-engine land ratings, the report said. He had about 3,800 total flying hours, with 552 hours in the DC-9 (all as first officer). He held an FAA first-class medical certificate with no restrictions or limitations, the report said.

The first officer was hired by ValuJet Airlines in 1994, as a first officer on the DC-9, the report said. He had been in the U.S. Navy between 1982 and 1991 and had flight experience in the Lockheed Martin P-3 (an antisubmarine patrol aircraft equipped with four turbo-propeller engines), the report said.

In reviewing his activities, the report said that the first officer "reported for duty the day of the accident at 1328, following two days off duty."

Postaccident toxicological samples were obtained from the flight crew for analysis. "The samples were analyzed and found to be negative for [alcohol] and other drugs of abuse," the report said.

The background and qualifications of the flight attendants were reviewed. At the time of the accident, two flight attendants occupied the aft-facing jumpseats in the forward cabin, the report said. One of the flight attendants had completed her initial training with ValuJet in 1994. "She had been previously employed as a flight attendant with Eastern Airlines for 7-1/2 years and with Private Jet for 1-1/2 years," the report said.

The other flight attendant in the forward cabin had also completed her initial training in 1994. "She had no prior flight attendant experience," the report said. The flight attendant who occupied the jumpseat in the rear cabin had completed her initial training in 1993 and had no prior flight attendant experience, the report said.

Postaccident toxicological samples were taken from the two uninjured flight attendants. The samples tested negative for alcohol and drugs, the report said. A sample was requested from the injured flight attendant, but she had already been hospitalized and treated for her injuries. Therefore, no toxicological sample was obtained, the report said.

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***"One of the flight attendants in the forward section of the cabin saw flames around the flight attendant in the aft jumpseat ... ."***

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The actions of the flight crew and cabin crew during the cabin fire and subsequent aircraft evacuation were reviewed. When the cabin fire erupted, "one of the flight attendants in the forward section of the cabin saw flames around the flight attendant in the aft jumpseat and tried to notify the flight crew of the fire by opening the cockpit door," the report said. "As required by FAA regulations, the cockpit door was locked."

One of the forward flight attendants went to locate the cockpit door key, which was stored in the galley, in accordance with ValuJet procedures, the report said. At the same time, the other forward flight attendant opened the cockpit door with her own key and informed the flight crew of the fire. "The captain then ordered an evacuation through the forward exits," the report said.

### **Standard Emergency Signal to Flight Crew Not Used**

The report said that at the time of the accident, ValuJet's flight attendant manual provided the following guidance in the event of an accident: "If life-threatening conditions exist inside the cabin, the first crew member aware of the situation shall notify the pilots via the interphone using the emergency signal (six chimes)," the report said. "If no response, unlock the cockpit door and evaluate conditions. If able, the captain will evaluate the situation and, if necessary, initiate an evacuation with the PA announcement of 'evacuate, evacuate, evacuate,'" the report said.

The flight attendant manual further stated: "If a life-threatening situation exists inside the cabin and you are unable to contact the cockpit [crew], begin shouting the appropriate commands. Once the aircraft comes to a complete stop, initiate the evacuation."

The flight crew was not aware that there was a fire in the cabin until the flight crew was notified by the flight attendant who opened the cockpit door. "The flight attendant, however, did not follow ValuJet's procedure that required the use of the interphone six-chime emergency signal to inform the cockpit [crew] of the fire," the report said.

"Because of the need for a flight attendant to retrieve a cockpit [door] key from its storage area in the galley before being able to unlock the cockpit door, use of the six-chime signal would probably have been a faster way to notify the cockpit [crew] about the fire." The report said that ValuJet procedures required the cockpit door key to be stored in the galley, but it did not explain why one cabin attendant had her own key or why neither flight attendant used the six-chime emergency signal to notify the pilots of the cabin fire.

The report noted: "The [NTSB] has some concerns regarding the use of the interphone as the sole means of notifying the cockpit [crew] of an onboard fire. In an emergency situation, the cockpit crew may be too busy with other emergency tasks to immediately answer the interphone. In fact, the [NTSB] has investigated accidents in which the flight attendant's interphone calls were not answered."

The report concluded that "all flight attendants should be able to quickly access the cockpit when appropriate. Therefore, the [NTSB] believes that the FAA should require that each flight attendant have a cockpit [door] key in his/her possession at all times while on duty."

During the investigation, the NTSB found "deficiencies in ValuJet's flight attendant training program, including emergency-drills training, and the FAA's oversight of this program," the report said. "Although these deficiencies did not affect the occupant survivability of this accident, they could adversely affect the outcome of future emergency situations."

Investigators found that ValuJet's flight attendant training syllabus did not include hands-on operation of the tailcone release handle. "As a result of the [NTSB's] accident investigation, ValuJet purchased a tailcone training device to ensure that flight attendants receive the required training," the report said.

Investigators discovered several errors in ValuJet's DC-9 flight attendant manual. Although the tailcone exit's operation was described correctly, the report said, the manual used an

illustration of the aft entrance door for a McDonnell Douglas MD-80 rather than the DC-9-32; a note on a diagram for the tailcone-interior jettison handle also referred to the MD-80 rather than the DC-9-32; and another diagram showed ValuJet's airplanes having both a tailcone exit door and an exit hatch, although ValuJet's DC-9s did not have an exit hatch.

"The flight attendant manual also contained incorrect information, or lack of information, regarding flight-attendant flotation equipment, passenger-safety announcements, flight-attendant operation of the cabin emergency lighting switch and use of the water fire extinguisher." ValuJet issued a new flight attendant manual in November 1995 that does not contain the previous edition's errors, the report said.

The NTSB expressed concern that "the deficiencies in the flight attendant training program and the flight attendant manual raise serious questions about the adequacy of the FAA's review of the program and the manual before approval and acceptance by the FAA in 1993," the report said. "Although the deficiencies noted in this accident were subsequently addressed by the air carrier, the [NTSB] believes that the FAA should emphasize to its POIs [principal operations inspectors] the importance of thoroughly reviewing flight attendant training programs before approving them and manuals before accepting them," the report said.

The report also noted that during the evacuation of the accident aircraft, "all four overwing exits were opened by passengers before the aircraft came to a complete stop," the report said. "This is contrary to the ValuJet flight attendant training manual, which states that an evacuation should not be initiated until the aircraft has come to a

complete stop. However, there is no indication that the flight attendants would have been able to prevent the passengers from opening the exit[s]," the report said.

The investigation reviewed the survival aspects of the accident flight. "About one-half of the available cabin seats were occupied," the report said. The passenger manifest listed one lap-child who was older than 24 months. FARs Part 121.311(b) "requires that all passengers more than 24 months of age be restrained during takeoff and landing," the report said.

The report noted: "According to passenger interviews, the child was seated on the lap of a female adult in the 21E window seat. During the evacuation, the adult handed the child to a male passenger, who carried the child through the right overwing emergency exit to another passenger, who carried the child across the wing and, holding the child, jumped off the trailing edge of the wing to the runway without injury."

In reviewing the evacuation of the aircraft, investigators found that "all exits and evacuation slides, except the tailcone exit (which was blocked by the aft cabin fire), were unobstructed

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***Investigators discovered  
several errors in  
ValuJet's DC-9 flight  
attendant manual.***

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and were used during the evacuation,” the report said. “Some passengers who saw the fire in the aft section of the cabin released their seat belts and moved toward exits before the airplane came to a stop,” the report said.

The actions of the flight crew during the evacuation were examined. “The captain reported that as he and the first officer were accomplishing the evacuation checklist, the smoke in the cockpit became thick, black and acrid and was lowering rapidly,” the report said. “The first officer reported that he was reading the evacuation checklist and had verified that the brakes were set and the spoilers were retracted, [and that he] had lowered the flap handle and had pulled the No. 1-engine fire handle (the captain had pulled the No. 2 [-engine] handle), after which he could hardly breathe.”

The report continued: “The first officer stated that he yelled to the captain that ‘we’ve got to get out of here,’ before they were able to place the emergency light switch (the fourth, and next, item in the evacuation checklist) in the ‘on’ position.”

During the evacuation, “the captain reported that as the first officer stood up, [the captain] could not see [the first officer] from the chest up,” the report said. The first officer reported that when he exited the cockpit into the cabin, “he could feel people walking past him, but he could see them only from the waist down. He stated that when he no longer felt anyone passing by, he exited through the front left door of the airplane,” the report said.

The report noted: “The captain stated that when he exited the cockpit, he dropped to the floor and could see ‘some distance down the aisle, but only within about [five centimeters to 7.6 centimeters (three inches to four inches)] of the floor.’ According to passengers, the fire spread rapidly and fully engulfed the cabin area within about three minutes after the engine fire.”

When interviewed about the evacuation, passengers reported that “the emergency floor track lighting illuminated briefly, but then extinguished,” the report said. “The captain reported that his initial attempt to broadcast the evacuation announcement over the PA system had not been successful; he then moved the emergency power switch to the ‘on’ position (which caused the emergency lights to turn off) and repeated the announcement,” the report said.

The report explained that “the manual selection of emergency electrical power restores power to the emergency DC [direct current] bus from the aircraft’s batteries; however, unless the emergency light switch is first moved from the ‘armed’ to the ‘on’ position, this action will also extinguish the emergency lights and resume charging of the battery packs. Placing the cabin emergency lighting switch to the ‘on’ position was the

fourth item on the ValuJet emergency evacuation checklist. ... Manual selection of emergency electrical power restores power to the PA system.”

The report also noted: “One passenger reported that the injured flight attendant in the aft jumpseat was struggling to release her seat belt and that as he moved aft to assist her, she released the belt and moved forward to escape through a left overwing exit. Several passengers described difficulty with visibility because of the smoke.”

## **Cabin Furnishings’ Compliance with Flammability Standards Reviewed**

The investigation reviewed the cabin furnishings of the accident aircraft for compliance with FAA flammability standards. In 1985, the FAA issued a regulation that established new fire-test criteria and “required that the cabin interiors of airplanes manufactured after 1985 and used in air carrier service comply with these new criteria; and [it also] required that cabin interiors of all other airplanes type certified after Jan. 1, 1958, and used in air carrier service, comply with these new criteria upon the first ‘general retrofit’ of the cabin interior,” the report said.

The accident aircraft “was manufactured before the effective date of the 1985 regulation and, therefore, any retrofit of fire-retardant cabin furnishings was required only in the event of a ‘general retrofit’ by the carrier,” the report said. “Piecemeal replacements of cabin furnishings, except for fire-blocked seat covers, are not required to meet the new flammability standards.”

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***“Piecemeal replacements of cabin furnishings, except for fire-blocked seat covers, are not required to meet the new flammability standards.”***

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The report concluded: “Thus, it is reasonable to expect that if an air carrier applied this regulation, as written, an airplane [could be] in service for 20 or more years [and] never be subjected to a ‘general retrofit.’”

Burn tests were conducted on selected pieces of cabin furnishings from the accident aircraft at the FAA Technical Center in Atlantic City, New Jersey. All of the samples tested from the accident aircraft met the pre-1985 FAA flammability-test requirements, the report said.

The report said that the accident “demonstrates the importance of the current standards and the need for existing aircraft to be brought up to these standards as quickly as possible.”

“ValuJet’s flight attendant manual in effect at the time [of the accident] listed standard uniform items for ValuJet flight attendants as trousers, shorts (optional), polo shirt (short- or long-sleeve), sweater (optional), a jacket, white socks and white shoes,” the report said. The report noted that the aft flight

attendant who was injured was wearing shorts and a short-sleeve polo shirt. If she had been wearing a long-sleeve shirt and trousers made from natural-fiber fabrics, “she [might] not have been burned,” the report said.

As a result of its investigation, the NTSB developed a number of findings, the most significant of which were:

- “An uncontained failure of the right engine occurred at low airplane [speed] and high engine-rotational speed, during the initiation of the takeoff roll. As a result of the uncontrolled failure, engine fragments penetrated the airplane’s cabin, severing the right-engine main fuel line and causing release of pressurized fuel inside the cabin. Sparks that most likely were generated by steel engine fragments contacting steel galley components ignited a fire that quickly spread through the airplane’s cabin;
- “The uncontained failure was caused by a fatigue crack ... in the seventh-stage HPC disk. The fatigue-crack length was consistent with a critical crack length [that would be] expected to produce separation of the disk under normal operating conditions;
- “Based on an analysis of fatigue striation measurements, a detectable crack existed ... in the seventh-stage [HPC] disk ... when the disk was overhauled by the THY repair station in 1991;
- “The ... disk ... did not receive a proper inspection when the disk was overhauled at the THY repair station in 1991;
- “Had the THY repair station accomplished a proper inspection of the ... disk, ... the crack would probably have been detected [and] the part rejected, and, consequently, the accident might have been avoided;
- “The THY repair station was not using ‘process sheets’ at the time of the 1991 overhaul and inspection of the ... disk; the use of such documents would have increased the likelihood that the disk would have received a proper inspection and that the crack would have been detected;
- “Although the Pratt & Whitney JT8D engine manual could have presented more precise information in terms of overhaul procedures and instructions, this lack of clarity did not contribute to the failure of the disk;
- “FAA guidance on what degree of detail is required in maintenance records is insufficient and vague;
- “Foreign repair stations are not, but should be, subject to the same FAA record-keeping requirements as domestic repair stations;

- “The industry practice of using serviceable tags without a clear understanding of their purpose can result in misinterpretation of the intent of these tags;
- “Although there were conflicting interpretations of THY’s authority to overhaul JT8D engines by the FAA and THY, the Repair Station Operations Specifications in question can reasonably be read to indicate that THY did have authority under [FARs] Part 145 to overhaul JT8D engines at the time [the engine] was overhauled in 1991;
- “The fourth item on the evacuation checklist was not completed by the flight crew because of smoke accumulation in the cockpit; as a result, emergency lights were not available during a portion of the evacuation. Fortunately, the lack of emergency lights did not preclude a successful evacuation;
- “Although the pilot’s delay in communicating the evacuation order because of an electrical power loss did not adversely affect the evacuation, the accident again highlights the need for an independent power source for [PA] systems in transport-category airplanes;
- “Although deficiencies in ValuJet’s flight attendant training program, including emergency drills training, and the FAA’s inadequate oversight of this program did not affect occupant survivability in this accident, they could have;
- “Although [U.S. FARs] require that all passengers more than 24 months old be restrained during takeoff and landing, this accident again demonstrates that this regulation is not always enforced, as one child who was more than 24 months old was listed as a lap child and was seen being held in an adult passenger’s lap;
- “Because one of the flight attendants had her own key for the cockpit, she was able to quickly notify the flight crew about the fire. ValuJet procedures in effect at the time did not provide for prompt flight attendant access to the cockpit; [and,]
- “The aircraft involved in this accident did not meet current regulatory requirements regarding flammability standards for materials used in the interiors of transport-category airplane cabins, nor was it required to do so. However, this accident demonstrates the importance of the current standards and the need for existing aircraft to be brought up to these standards as quickly as possible.”

As result of its findings, the NTSB made the following recommendations to the FAA:

- “Review Air Agency Certificates and Repair Station Operations Specifications of all repair stations and ensure

that the language used in the operations specifications clearly indicates the extent of the repair station's authority;

- “Revise [FARs] Part 145 to require Subpart C foreign repair stations to adhere to the same record-keeping requirements as domestic repair stations;
- “Revise all the applicable regulations and provide specific guidance on the documentation to be used and kept during inspections and overhauls, including ‘process sheets’ or similar detailed documentation for all certificated repair stations;
- “Require that ‘serviceable tags’ be used to return engines and other components to service, that they be in a prescribed format ... and that when there is a change of ownership, and certainly upon importation, [that] the approval for return to service attest to the overall airworthiness of the part and [the] tag reflect that a complete and thorough review of records, including ‘process sheets’ of the last overhaul, has taken place. In the absence of such records, require an overhaul of the part when there is a change in ownership;
- “Require that all transport-category aircraft manufactured before Nov. 27, 1990, be retrofitted with a [PA] system capable of operating on an independent power source;
- “Emphasize to [FAA POIs] the importance of thoroughly reviewing flight attendant training programs before approving them and flight attendant manuals before accepting them;
- “Provide guidance on how to implement the requirement that occupants who are more than 24 months old are restrained during takeoffs, landings and during turbulence;
- “Require that each flight attendant have a cockpit [door] key in his/her possession at all times while on duty;
- “Prohibit the use during any type of replacement, after 1997, of cabin materials in all transport-category airplanes that do not comply with the current fire safety standards contained in [FARs Part] 25.853;
- “Amend [FARs] Part 121 to prohibit, upon transfer of the aircraft from one certificate holder to another, or by Jan. 1, 2001, whichever occurs first, the operation of

airplanes with cabin materials that do not meet the requirements of [FARs] Part 25.853;

- “Issue an operations bulletin recommending that [POIs] advise their air carriers to disseminate [FAA] safety guidance on airline-passenger attire to their flight attendants; [and,]
- “Require all aircraft currently required to be installed with a [CVR] to be retrofitted within two years with a CVR installation designed such that an uninterrupted recording from the boom or mask microphones and headphones for each flight crew member's position and from an area microphone can be made on dedicated channels of the CVR. A sidetone shall be produced only when the transmitter or interphone is selected, and, in addition, all audio signals received by hand-held microphones shall be recorded on the respective crew member's channel when keyed to the “on” position.”♦

Editorial note: This article was adapted from *Uncontained Engine Failure/Fire, ValuJet Airlines Flight 597, Douglas DC-9-32, N908VJ, Atlanta, Georgia, June 8, 1995*. Report no. NTSB/AAR-96/03, prepared by the U.S. National Transportation Safety Board. The 131-page report contains photographs, figures and appendices.

## Further Reading from FSF Publications

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