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Foreign-object Damage Cripples Concorde on Takeoff From Paris

The aircraft had accelerated beyond V_1 when a tire burst and a fuel tank ruptured. Debris and a fuel-fed fire caused a reduction of thrust from the two left engines. The crew continued the takeoff but were unable to retract the landing gear. The aircraft was airborne about one minute before striking terrain.

FSF Editorial Staff

At 1644 on July 25, 2000, a BAE Systems/EADS (European Aeronautic Defense and Space Co.) Concorde, operated by Air France as Flight 4590, struck terrain in Gonesse, France, after receiving foreign-object damage during takeoff from Runway 26R at Charles de Gaule Airport in Paris. The nine crewmembers and 100 passengers were killed. Four people on the ground were killed, and six people were injured. The aircraft was destroyed.

The French Bureau Enquêtes-Accidents (BEA) said, in its final report, that the probable causes of the accident were the following:

- "High-speed passage of a tire over a part lost by an aircraft that had taken off five minutes earlier, and the destruction of the tire;
- "The ripping out of a large piece of [fuel] tank in a complex process of transmission of the energy produced by the impact of a piece of tire at another point on the tank; this transmission [involved] deformation of the tank skin and the movement of the fuel, with perhaps the contributory effect of other more minor shocks and/or a hydrodynamic pressure surge; [and,]
- "Ignition of the leaking fuel by an electric arc in the landing-gear bay or through contact with the hot parts of the engine, with forward propagation of the flame causing a very large fire under the aircraft's wing, and severe loss of thrust on engine [no.] 2, then engine [no.] 1."

The report said, "In addition, the impossibility of retracting the landing gear probably contributed to the retention and stabilization of the flame throughout the flight."

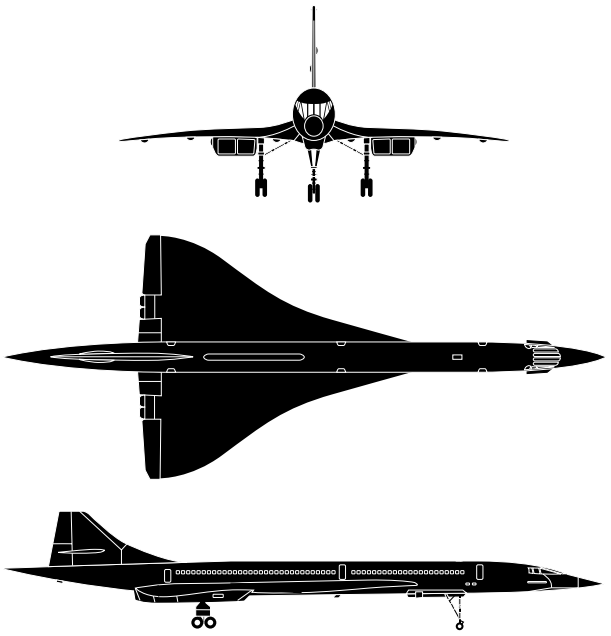
The accident occurred as the aircraft departed for a charter flight to New York, New York, U.S. The captain was the pilot flying.

The captain, 54, held an airline transport–transoceanic and polar (ATP-TOP) license and type ratings in the Airbus A300, A320 and A340, the Boeing 727 and 737, and the Concorde. He earned the Concorde type rating in August 1999. The captain had 13,477 flight hours, including 317 flight hours (284 flight hours as captain) in the Concorde.

The first officer, 50, held an ATP-TOP license and type ratings in the A300, Aerospatiale Caravelle, Concorde, Morane Saulnier 760 and Nord 262. He earned the Concorde type rating in January 1989. The first officer had 10,035 flight hours, including 2,698 flight hours as first officer in the Concorde.

The flight engineer, 58, held a flight engineer license with ratings in the Boeing 727 and 747, Caravelle and Concorde. He had 12,532 flight hours, including 937 flight hours in the Concorde.

The aircraft, serial no. 3, entered airline service in October 1979 and had accumulated 11,989 flight hours and 4,873 cycles. During a scheduled maintenance check in July 2000, a spacer was omitted when the aircraft's left-main-landing-gear assembly was replaced to correct a defect in the tire-underinflation-detection system. The aircraft completed four flights after the maintenance check. The report said that the omission of the spacer did not contribute to the accident.



BAE Systems/EADS Concorde

The Concorde was designed and manufactured by Aerospatiale and British Aircraft Corp. The prototype first flew in 1970. Deliveries of production airplanes began in 1975 and ended in 1978. The type certificate for the supersonic transport currently is held by BAE Systems (formed in 1999 by the merger of British Aerospace and Marconi Electronic Systems) and EADS (the European Aeronautic Defense and Space Co., formed in 2000 by the merger of Aerospatiale Matra, CASA [Construcciones Aeronauticas SA] and DaimlerChrysler Aviation).

The Concorde accommodates three flight crewmembers and up to 128 passengers.

Control surfaces comprise six elevons on the trailing edge of the wing and two integral rudders. Trim and balance are maintained by moving fuel from transfer tanks in the wings and in the rear fuselage. Up to 94,470 kilograms (208,269 pounds) of fuel can be carried in 13 tanks.

Maximum takeoff weight is 185,070 kilograms (408,005 pounds). Maximum landing weight is 111,130 kilograms (244,997 pounds).

The Concorde has four Rolls-Royce/SNECMA Olympus 593-610 turbojet engines, each producing a maximum of 17,260 kilograms (38,051 pounds) thrust on takeoff with reheat (afterburner). Maximum operating altitude is 60,000 feet. Maximum operating cruise speed is 2.04 Mach.♦

"The aircraft was airworthy, and there were no acceptable deferred defects for Flight 4590," the report said.

The report said that the aircraft was "slightly overloaded." The Concorde's maximum takeoff weight is 185,070 kilograms (408,005 pounds). A dispatch form for the accident aircraft showed a computer-generated takeoff weight of 184,880 kilograms (407,586 pounds). Investigators estimated that the takeoff weight was 185,880 kilograms (409,791 pounds). The difference primarily was due to estimates of fuel consumption during taxi: The dispatch form indicated that 2,000 kilograms (4,409 pounds) of fuel would be consumed during taxi; investigators estimated that 1,000 kilograms (2,205 pounds) of fuel was consumed during taxi.

"Any effect on takeoff performance from this excess weight was negligible," the report said.

Visual meteorological conditions prevailed at the airport. Visibility was 15 kilometers (nine statute miles), and there were scattered cumulus clouds with bases at 1,800 feet. Temperature was 19 degrees Celsius (66 degrees Fahrenheit). Average winds at the threshold of Runway 26 were from 090 degrees at three knots.

At 1634, the ground controller told the crew to taxi from the gate to Runway 26R, which was 4,215 meters (13,829 feet) long and 45 meters (148 feet) wide. The controller asked the crew if they wanted to conduct the takeoff from a runway intersection or from the approach end of the runway. The first officer said, "We need the whole runway." The controller told the crew to taxi to the approach end of the runway and to hold short of the runway.

The flight crew selected 150 knots for V_1, 198 knots for V_R and 220 knots for V_2. [European Joint Aviation Requirements (JARs) 1.2 defines V_1 as "the maximum speed in the takeoff at which the pilot must take the first action (e.g., apply brakes, reduce thrust, deploy speed brakes) to stop the airplane within the accelerate-stop distance; V_1 also [is] the minimum speed in the takeoff, following a failure of the critical engine at V_{EF}, at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance." JARs 1.2 defines V_{EF} as "the speed at which the critical engine is assumed to fail during takeoff." JARs 1.2 defines V_2 as the "takeoff safety speed."] The report defined V_R as the rotation speed.

While holding for takeoff, the captain conducted a departure briefing. He said, "Between zero and 100 knots, I stop for any aural warning, the tire flash [i.e., underinflated-tire-warning light] and failure callout from you, right. Between 100 knots and V_1, I ignore the gong [aural master warning], stop for an engine fire, a tire flash and the failure callout. After V_1, we continue on the SID [standard instrument departure] we just talked about. We land back on runway twenty-six right. And the quick reference handbook is ready for an overweight

landing." [Concorde's maximum landing weight is 111,130 kilograms (244,997 pounds).]

At 1640, the local controller told the crew to taxi the aircraft into position on the runway. Two minutes later, the controller cleared the crew for takeoff and said that the wind was from 090 degrees at eight knots.

"This announcement did not result in any comment on the part of the crew even though, with those wind conditions [i.e., an eight-knot tail wind], the takeoff weight should be reduced to 180,300 kilograms [397,489 pounds] because of the tire-speed limit," the report said. "In reality, the wind was practically zero. … However, even if the crew had previously noticed this absence of wind — for example, by observing the indication given by the windsock near the threshold of Runway 26L around a thousand meters [3,281 feet] away, it is difficult to understand the absence of any comment on their part."

The captain said, "Is everybody ready?" The first officer and the flight engineer said yes. The captain then said, "To one hundred; V-one, one hundred fifty."

The crew began the takeoff at 1642:31. At 1642:54, the first officer called 100 knots. The captain said "checked." The flight engineer said "four greens," which refers to indications by "go lights" of normal engine operation. At 1643:03, the first officer called V_1.

"A few seconds after that, tire no. 2 (right front) on the left-main landing gear was destroyed after having run over a piece of metal lost by an aircraft that had taken off five minutes before," the report said. "The destruction of the tire in all probability resulted in large pieces of rubber being thrown against the underside of the left wing and the rupture of part of tank 5." (Tank no. 5 is one of 13 fuel tanks in the Concorde.)

Calibrated airspeed was 175 knots when the tire burst. The report said that a fuel stain on the runway indicated that a large quantity of fuel leaked from the tank before the fire began.

Several witnesses heard explosions and observed thick black smoke and flames under the left wing, between the left-engine nacelle and the fuselage.

"Some people reported seeing pieces fall on the runway immediately after the first noise of explosion," the report said. "The noises of explosion were immediately interpreted [by maintenance technicians] as being from engine surges."

The no. 1 engine and the no. 2 engine surged at 1643:13. The report said that the no. 1 engine surge likely was caused by ingestion of debris from the burst tire or ingestion of hot gases from the fire and resulted in a thrust reduction to about 75 percent of nominal takeoff thrust. The no. 2 engine surge likely was caused by ingestion of hot gases and resulted in a thrust reduction to about 3 percent of nominal thrust. The go lights for engine no. 1 and engine no. 2 extinguished.

When thrust from the left engines decreased, the aircraft began to veer toward the left side of the runway. The report said that postaccident tests in a flight simulator indicated that when thrust is lost from both engines on one side of the aircraft, "the visual sensation is that of an imminent lateral runway excursion."

Calibrated airspeed was 183 knots when the captain began to rotate the aircraft at a rate less than the normal rotation rate. He also applied right rudder and a slight amount of right aileron.

"The crew [experienced] a totally unknown, highly dynamic situation with no pre-established solution to face it in a phase of flight where, having passed V_1, they were mentally prepared for rotation," the report said. "In this exceptional and unknown environment, the decision to take off as soon as possible appears to have become compelling. The rate of the rotation also appears to confirm that the pilot was conscious of taking off at a speed below V_R."

The first officer said, "Watch out."

The flight engineer then made a statement that was not transcribed conclusively from the cockpit voice recorder (CVR) recording; the report said that the statement might have been "stop."

About the same time, the controller said, "Concorde zero … four five nine zero, you have flames … you have flames behind you." The first officer acknowledged the controller's transmission.

A few seconds later, the CVR recorded a radio transmission from an unidentified source: "It's really burning, and I'm not sure it's coming from the engines." The report said that this transmission may have been made by a flight crewmember of an aircraft holding for takeoff.

The engine no. 1 go light illuminated, indicating that the engine had recovered from the surge and was producing nearly nominal thrust. Engine no. 2 did not recover from the surge, and its go light remained extinguished.

At 1643:20, the flight engineer said, "Failure, engine two." Two seconds later, the aural engine-fire warning activated, and the flight engineer said, "Shut down engine two." The captain then told the first officer and the flight engineer to conduct the engine fire procedure.

The report said that sounds recorded by the CVR indicate that the no. 2 engine throttle lever was moved to the "STOP" position and that the no. 2 engine fire handle was pulled.

At 1643:23, engine no. 1 ingested hot gases and/or fuel and surged again; thrust decreased to about 4 percent of nominal thrust. The engine then began to recover from the surge, and thrust increased.

At 1643:27, the first officer said, "Watch the airspeed, the airspeed, the airspeed." Indicated airspeed was 200 knots.

At 1643:30, the captain told the first officer to retract the landing gear. The aircraft was 100 feet above the ground and climbing 750 feet per minute.

At 1643:31, the controller said, "Four five nine zero, you have strong flames behind you." About six seconds later, the controller said, "So, do as you wish. You have priority for a return to the field." The first officer acknowledged both transmissions.

At 1643:39, the captain again told the first officer to retract the landing gear. The CVR then recorded a statement by the first officer; the report said that the statement likely was "I'm trying."

At 1643:46, the captain asked the flight engineer if he was shutting down engine no. 2. The flight engineer said, "I've shut it down."

At 1643:49, the first officer said, "The airspeed."

"This warning, repeated again about 10 seconds later, is explained by the fact that the speed remained at about 200 knots, lower than the normal climbout speed of 220 knots with a failed engine," the report said.

At 1643:56, the first officer said, "The gear isn't retracting."

The report said that the likely reason that the landing gear did not retract on command was the failure of the left-main-landing-gear door to open; the door might have been damaged by the tire burst and fire.

The ground-proximity warning system issued three aural warnings — "whoop, whoop, pull up" — between 1643:59 and 1644:02.

At 1644:11, the no. 1 engine, which had recovered from the second surge and was producing nearly nominal takeoff thrust, surged again and decelerated rapidly, resulting in total loss of thrust.

At 1644:18, the controller told aircraft rescue and fire fighting (ARFF) personnel that the Concorde was returning to land on Runway 09.

The first officer said, "Negative, we're trying for Le Bourget [Airport]." [Le Bourget is approximately seven kilometers (four nautical miles) southwest of de Gaulle.]

From 1644:17 to 1644:29, the aircraft's angle-of-attack increased from 12 degrees to more than 25 degrees, and left bank increased from two degrees to 113 degrees. The CVR recorded noises that were identified by investigators as the movement of throttle levers to the "IDLE" position. Thrust from the no. 3 engine and no. 4 engine then rapidly decreased.

"This reduction in thrust on engines 3 and 4 was probably intended to decrease the strong bank to the left caused by the significant thrust asymmetry and by the destruction of vital control surfaces by fire," the report said. "This decrease in thrust on these two engines was accentuated by a surge due to airflow distortion caused by the angle-of-attack and the level of yaw reached at that moment.

"In these extreme conditions, the combination of lateral [asymmetry] and thrust asymmetry, and the major thrust/drag imbalance, which could not be compensated for by a descent, led to a loss of control. This loss of control was probably accelerated by the structural damage caused by the fire."

The aircraft struck terrain about 9.5 kilometers (5.1 nautical miles) southwest of the threshold of Runway 26R. The report said that the aircraft struck and "almost entirely flattened" a hotel.

"Examination of the site showed that the aircraft had struck the ground on [a heading of 120 degrees], practically flat with little forward speed," the report said. "After the impact, it broke and spread generally to the south, with the aircraft upright. … Most of the wreckage, with the exception of the cockpit, remained within a rectangle measuring 100 meters [328 feet] long by 50 meters [164 feet] wide."

ARFF personnel in 12 vehicles and personnel from fire stations near the airport responded to the accident. The fire was brought under control three hours after firefighters arrived at the accident site.

"The crew were all found at their takeoff positions and the passengers in the seats assigned at boarding," the report said. "The seats were fragmented. All the seat belts were fastened. The circumstances of the accident and the damage to the aircraft meant that the accident was not survivable."

The report said that three inspections of the airport movement area (i.e., runways, taxiways and aprons) were required each day — the first before 0700, the second about 1400 and the third about 2100. On the day of the accident, the first inspection was conducted at 0430. The second inspection, which was planned for 1500, was postponed because of an ARFF exercise and was not conducted before the accident aircraft's departure.

After the accident, a piece of metal 43 centimeters (17 inches) long, 29 millimeters to 34 millimeters (1.1 inches to 1.3 inches) wide and 1.4 millimeters (0.06 inch) thick was found on the runway. The report said that the piece of metal was a stainless steel wear strip that had fallen from the lower-left engine-fan-reverser cowl on the no. 3 engine on a Continental Airlines McDonnell Douglas DC-10 that had departed five minutes before the accident aircraft.

"When closed, the fan-reverser-cowl assembly made it practically impossible to note the absence of the [wear] strip," the report said.

Maintenance documents for the DC-10 indicated that wear strips on the no. 3 engine fan-reverser cowl had been replaced in Tel Aviv, Israel, by Israel Aircraft Industries during scheduled maintenance June 11, 2000.

"Further work was carried out at Houston [Texas, U.S., on July 9, 2000,] on this engine's reverser cowl," the report said. "The mechanical report states that the lower-left wear strip was changed during the job. The technician who completed this report stated that he had noticed a twisted wear strip that was sticking out of the cowl. The job was performed specifically to replace it."

The report said that the wear strip installed in Houston did not conform with the manufacturer's specifications.

"The engine cowl support was drilled with 37 holes, whereas the installation of the strip requires only 12," the report said. "A titanium piece was used in Houston, along with a mastic which is not normally used for this operation. Finally, the lower-right wear strip was too long … which helps to explain the successive tearing off of the strip located opposite [i.e., the lower-left wear strip]."

The report said that before the accident, Concordes were involved in 57 incidents in which tires burst or deflated. The report said that analyses of the incidents showed the following:

- "Twelve of these events had structural consequences on the wings and/or the tanks, of which six led to penetration of the tanks;
- "Nineteen of the tire bursts/deflations were caused by foreign objects;
- "Twenty-two events occurred during takeoff;
- "Only one case of tank penetration by a piece of tire was noted; [and,]
- "None of the events identified showed any rupture of a tank, a fire or a significant simultaneous loss of power on two engines."

The report said that analyses of the six incidents involving fuel-tank penetration showed the following:

- "Four of these events occurred during takeoff. Among these, in one case the tire damage was caused by an object on the runway, in two cases the tire burst occurred for reasons [that] were not determined, the final case being due to tire deflation while the aircraft was rolling at high speed. One of these events resulted in an aborted takeoff; in three others, the aircraft took off and then returned to land;
- "One event occurred on landing. The tire burst was caused by a braking-system jam; [and,]
- "The last event occurred during taxiing when the aircraft was leaving the runway. The tire burst was also due to a braking-system jam."

The first incident occurred June 14, 1979, and involved the greatest aircraft damage. An Air France Concorde was departing from Washington (D.C., U.S.) Dulles International Airport when a tire deflated. Tread that separated from the deflated tire caused another tire to burst and the destruction of a wheel. Debris punctured small holes in three fuel tanks. After several unsuccessful attempts to retract the landing gear and the failure of a hydraulic system, the crew landed the aircraft at the departure airport.

Investigation of the incident resulted in airworthiness directives requiring installation of a tire-underinflation-detection system, improved protection of the hydraulic brake system, inspection of the main-landing gear tires before takeoff and installation of reinforced wheels.

"As a result of studies carried out on the risks of damage from pieces of tire and [tests] to justify the integrity of the structure in case of direct penetration, it was concluded that it was not necessary to install protection for the underside of the wings," the report said.

After the Concorde accident in Paris, a large section of the bottom of the no. 5 fuel tank was found on the runway. The report said that the tank section had been "ripped away from the inside toward the outside." Another section of the tank had a puncture 10 millimeters (0.4 inch) wide and 40 millimeters (1.6 inches) long.

The report said that the rupture of the no. 5 fuel tank "was caused by a mechanism that had never been seen on civil aircraft before the accident and about which it is difficult to determine the precise process."

Postaccident tests indicated that the process might have involved a large piece of the burst tire striking the bottom of the fuel tank, causing deformation of the tank and displacement of fuel inside the tank. The tank was full of fuel, and the fuel displacement might have created a pressure wave that caused the tank to rupture.

Penetration of the tank by a piece of the burst tire might have contributed to the process by creating a hydrodynamic pressure surge, described in the report as follows:

> On penetrating the liquid [inside the tank], the projectile is rapidly slowed down. During this slowing, its kinetic

energy is transferred to the liquid, and a cavity of a certain volume is created around it. In case of confinement — that is to say, when the tank is full — the fluid, being incompressible, transmits to the structure a mechanical load dependent upon the volume of the cavity.

Investigators conducted tests in a flight simulator to determine what might have occurred if the captain had rejected the takeoff at 183 knots rather than rotating the aircraft for takeoff, or if the captain had rejected the takeoff at 196 knots, which would have corresponded with the accident aircraft's airspeed when the flight engineer said what is believed to have been "stop." The tests indicated that the aircraft would have overrun the runway at 74 knots or at 115 knots, respectively.

"These figures show that an aborted takeoff would have led to a runway excursion at such a speed that, taking into account the fire, the result would probably have been catastrophic for the aircraft and its occupants," the report said.

On Aug. 16, 2000, the BEA and the U.K. Air Accidents Investigation Branch (AAIB), which participated in the investigation, made the following urgent recommendation to the French Direction Générale de l'Aviation Civile (DGAC) and the U.K. Civil Aviation Authority (CAA):

> The certificates of airworthiness for Concorde [should] be suspended until appropriate measures have been taken to guarantee a satisfactory level of safety with regard to the risks associated with the destruction of tires.

The report said that the DGAC and the U.K. CAA required the following actions before returning the Concorde to service:

- "Installation of flexible linings in [six fuel] tanks;
- "Reinforcement of the electrical harnesses in the main-landing-gear bays;
- "Modification of flight manual procedures so as to inhibit power supply to the brake ventilators during critical phases of flight and revision of the MMEL [master minimum equipment list] to ensure that technical operational limitations cannot be applied for the tire-underpressure-detection system;
- "Installation of Michelin NZG tires and modification of the anti-skid computer;
- "Modification of the shape of the water deflector [on the main-landing gear] and removal of the [deflector's] retaining cable; [and,]
- "A ban on the use of volatile fuels and an increase in the minimum quantity of fuel required for a go-around." [The report did not explain the reasons for this action; the accident aircraft was refueled with Jet A-1 before departure.]

The report said, "The investigation did not bring to light the need for any other urgent recommendations. However, on several points, some improvements specifically linked to Concorde seem desirable in the light of information from the investigation. These improvements, which are the subject of the following recommendations, were brought to the attention of the French airworthiness authorities and were taken into account in the context of the aircraft's return to service [on Nov. 7, 2001]:

- "For any transport aircraft, it is essential that feedback, through analysis of in-service incidents, be as effective as possible. Taking into account the small number of [Concordes] in service and their limited operations, in-service experience on Concorde is particularly limited. [The Concorde] is, however, both an aging [aircraft] and a complex aircraft. It has been noted that the rate of malfunctions in certain systems or equipment was higher than current rates on other aircraft. Consequently, the BEA recommends that the airworthiness authorities, the manufacturers and the operators of Concorde reinforce the means available for the analysis of the functioning of aircraft systems and in-service events and for the rapid definition of corrective actions;
- "The Concorde flight manual stipulates that a red alarm [master warning light and gong] must lead to an immediate reaction by the crew. In the same manual, dealing with an engine fire is consistent with this general instruction. However, the *Air France Operations Manual* requires that no action be taken before reaching 400 feet. Consequently, the BEA recommends that Air France ensure that the emergency procedures in the section on Concorde utilization in its operations manual be coherent with the flight manual;
- "Recording the engine parameters [that] allow engine speed to be determined only every four seconds slowed down and complicated some work essential for the technical investigation. This characteristic also tends to mask certain facts during examination of incidents for which it would not be possible to devote as much time and effort as for the 25 July 2000 accident. In contrast to Air France's Concorde aircraft on the day of the accident, British Airways aircraft are equipped with [flight data] recorders that allow the parameters from all four engines to be recorded every second. Consequently, the BEA recommends that Air France equip its Concorde aircraft with recorders capable of sampling at least once a second the parameters that allow engine speed to be determined on all of the engines; [and,]
- "The technical investigation brought to light various malfunctions relating to the operation of the aircraft — for example, the use of non-updated flight-preparation data, the absence of archiving of certain documents or incomplete baggage management. Equally, omitting the [landing-gear] spacer was a consequence of non-respect

of established procedures and of the failure to use the appropriate tool. Consequently, the BEA recommends that the DGAC undertake an audit of Concorde operational and maintenance conditions within Air France."

The report said, "Beyond specific improvements to Concorde, the investigation showed the need for progress in safety in various areas. This general progress is the subject of the following recommendations:

- "Tests and research undertaken in the context of the investigation confirmed the fragility of tires against impacts with foreign bodies and the inadequacy of the tests in the context of certification. Recent examples on other aircraft than Concorde have shown that tire bursts can be the cause of serious damage. Consequently, the BEA recommends that the DGAC, in liaison with the appropriate regulatory bodies, study the reinforcement of the regulatory requirements and demonstrations of conformity with regard to aviation tires;

- "The investigation showed that a shock or a puncture could cause damage to a [fuel] tank according to a process of transmission of energy from a projectile. Such indirect processes, though known about, are complex phenomena which had never been identified on civil aircraft. Equally, the ignition of the kerosene leak, the possible forward propagation of the flame, its retention and stabilization occurred through complex phenomena, which are still not fully understood. Consequently, the BEA recommends that the DGAC, in liaison with the appropriate regulatory bodies, modify the regulatory certification requirements so as to take into account the risks of tank damage and the risk of ignition of fuel leaks;

- "In France, airport operations manuals contain instructions based on the ICAO [International Civil Aviation Organization] recommendations concerning the inspection of movement areas. However, there are not yet any national regulations concerning their surveillance. The DGAC is currently studying the implementation of such regulations. The accident showed that the presence of objects on this area presented a risk to safety. It also showed that the presence of certain objects on the runway might not be identified by any preventative measures. Consequently, the BEA recommends that the DGAC ensure the rapid implementation of programs for the prevention of debris on airports. These programs should involve all organizations and personnel operating on the movement area. [BEA recommends that] ICAO study the technical feasibility of an automatic detection system for foreign objects on runways;

- "The loss of a metallic strip by the Continental Airlines DC-10 has been identified as resulting from maintenance operations that were not in accordance with the [manufacturer's procedures]. Consequently, the BEA recommends that the FAA [U.S. Federal Aviation Administration] carry out an audit of Continental Airlines maintenance, both in the United States and at its foreign subcontractors;

  [FAA, on March 5, 2002, responded as follows:

  "The FAA's Certificate Management Office (CMO) assigned to Continental Airlines conducted over 40 inspections last year of Continental Airline's domestic and foreign maintenance facilities and those of its contractors. There are 19 similar inspections scheduled for those facilities in 2002.

  "The CMO also investigated each technician who was associated with replacement of the wear strip on the [DC-10 that departed five minutes before the] accident aircraft. The only finding, to date, was that a technician made an inappropriate manual reference in the logbook. Administrative actions were taken against the technician and Continental Airlines.

  "Continental Airlines conducted an internal investigation and inspected their entire DC-10 fleet for proper installation of the wear strip. The investigation concluded that the manufacturer's (General Electric) instructions for replacement of the wear strip were followed, but the instructions should be improved. As a result, Continental Airlines adopted supplemental procedures to provide additional security for wear-strip installations that are above and beyond those recommended by the manufacturer."]

- "The technical investigation again brought to light the current difficulty in identifying and analyzing certain crew actions, certain selector noises and visual alarms. On several occasions, the BEA and its fellow agencies abroad have recommended the installation of video recorders inside cockpits. This point was examined in September 1999 at ICAO during the Investigation and Prevention of Accidents divisional meeting (AIG 99), [which generated a request that proposals for video-recorder installation] be sent to the flight-recorder expert group (FLIREC). Consequently, the BEA recommends that ICAO fix a precise timetable for the FLIREC group to [propose] conditions for the installation of video recorders onboard aircraft undertaking public transport flights;

- "The investigation showed that the cabin crew had certainly perceived significant changes in their environment. It is therefore possible that communications between the cabin crew or attempts to communicate with the cockpit occurred. Exchanges between members of the cabin crew are not, however, recorded;

and [monitoring of the public-address system was deselected] by the flight engineer at [1614, which discontinued recording of cabin communications by the CVR]. Consequently, the BEA recommends that ICAO study the procedures for recording specific exchanges between cabin crewmembers and exchanges between the cockpit and the cabin;

- "The investigation showed that the crew were probably never conscious of the origin of the fire or of its extent. A comparable situation frequently occurs in the case of accidents due to damage to the structure of an aircraft. Consequently, the BEA recommends that DGAC, in liaison with the appropriate regulatory bodies, study the possibility of installing devices to [provide a visual display of] parts of the structure hidden from the crew's view or devices to detect damage to those parts of the aircraft;

- "The investigation showed that the lateral acceleration [experienced] by the Concorde crew as a result of the surges on engines 1 and 2 were different from the values recorded at the aircraft's center-of-gravity, these values being reproduced on flight simulators. The [accuracy] of the simulation is an important part in the quality of training. Consequently, the BEA recommends that DGAC, in liaison with the appropriate regulatory bodies, study the possibility of modifying the regulatory requirements relating to new flight simulators so that they accurately reproduce the accelerations really experienced in the cockpit; [and,]

- "Investigators and their advisers worked on the wreckage for several days without knowing that the accident site was polluted by asbestos used on the aircraft. They were therefore not equipped with special protective clothing, which may have long-term consequences on their health. This type of problem was examined at the ICAO [AIG 99], and the meeting formulated recommendations [about] information and training on the dangers of accident sites. Consequently, the BEA recommends that ICAO [implement the AIG 99 recommendations] in the shortest possible time and [that] the primary certification authorities ask manufacturers to immediately identify [and document] all potentially dangerous substances [that] are used in the manufacture of [their] aircraft."

[As of April 23, 2002, BEA had not received responses to its recommendations from DGAC and ICAO.]♦

[FSF editorial note: This article, except where specifically noted, is based on the French Bureau Enquêtes-Accidents (BEA) report: *Accident on 25 July 2000 at La Patte d'Oie in Gonesse (95) to the Concorde registered F-BTSC operated by Air France*. The report is an English translation by BEA of the official report, which was published in French. BEA said, "As accurate as the translation may be, the original text in French is the work of reference."]

Accident Prevention

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