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Stabilized Approach And Flare Are Keys to Avoiding Hard Landings

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Stabilized Approach and Flare Are Keys to Avoiding Hard Landings

Flight crews primarily use their judgment to identify and report hard landings, but recorded flight data also might be useful to gauge the severity of the impact before a conditional maintenance inspection is performed. The accident record shows that hard landings often involve substantial damage and sometimes result in fatalities.

— FSF EDITORIAL STAFF

Data show that, as an accident type, hard landings have accounted for the highest number of accidents worldwide among Western-built large commercial jet airplanes. Of 385 total accidents from 1993 through 2002, 54 were hard-landing accidents (Table 1, page 2).[1]

Accidents resulting from hard landings surpassed the number of accidents involving runway overruns on landing (52), excursions off the sides of runways on landing (42), landing gear failures during landing and takeoff (38) and controlled flight into terrain (CFIT; 33).[2]

Hard landings typically did not result in fatalities. The data for 1993 through 2002 show that 192 people were killed in all types of landing accidents; the leading killers were CFIT and loss of control in flight, each of which claimed more than 2,000 lives during the period.

Of the 70 hard-landing accidents examined for this article, three involved fatalities and serious injuries; another accident involved serious injuries but no fatalities (see "Turbojet Airplane Hard-landing Accidents and Incidents, 1996–2002," page 17).[3] Sixty-six accidents involved minor injuries and/or no injuries.

Table 1
Accidents Involving Western-built Large Commercial Jet Airplanes, 1993–2002[1]

						Landing																						
Airplane Generation	Controlled Flight Into Terrain	Loss of Control	Midair Collision	In-flight Fire	Fuel Tank Explosion	Off End on Landing	Off Side on Landing	**Hard Landing**	Landed Short	Landing-gear Collapse/Fail/Up	Ice/Snow	Fuel Management/Exhaustion	Wind Shear	Takeoff Configuration	Refused Takeoff — Off End	Off Side on Takeoff	Runway Incursion Vehicle/People	Wing Strike	Engine Failure/Separation	Ground Collision	Ground Crew Injury	Boarding/Deplaning	Turbulence Fatality	Miscellaneous[2]	Fire on Ground	Aircraft Structure	Unknown	**Total**
First[3]	3	6	0	1	0	7	3	3	3	6	0	2	0	1	1	0	0	2	1	0	0	0	0	2	1	0	2	**44**
Second[4]	16	5	0	4	0	17	23	11	10	12	2	2	1	1	6	1	1	1	1	2	1	0	0	3	1	2	4	**127**
Early wide-body[5]	3	0	1	1	1	4	2	5	1	5	1	1	0	0	3	2	0	0	5	3	1	0	1	3	3	2	0	**48**
Current[6]	11	12	1	1	1	24	14	35	3	15	1	2	1	2	3	3	8	0	4	4	1	2	1	8	3	2	4	**166**
Total	**33**	**23**	**2**	**7**	**2**	**52**	**42**	**54**	**17**	**38**	**4**	**7**	**2**	**4**	**13**	**6**	**9**	**3**	**11**	**9**	**3**	**2**	**2**	**16**	**8**	**6**	**10**	**385**

[1] Data include airplanes heavier than 60,000 pounds/27,000 kilograms maximum gross weight, except those manufactured in the Commonwealth of Independent States and commercial airplanes in military service.

[2] Miscellaneous accidents included the following: coffee-maker explosion, instrument error, flight attendant fall from door, jet blast, pilot incapacitation and turbulence injury.

[3] First-generation airplanes include the following: Boeing 707 and B-720; Breguet Mercure; Convair CV-880/-990; de Havilland Comet 4; Douglas DC-8; and SUD-Aviation Caravelle.

[4] Second-generation airplanes include the following: Boeing 727 and B-737-100/-200; British Aircraft Corp. BAC 1-11; de Havilland Trident; Fokker F.28; Douglas DC-9; and Vickers VC-10.

[5] Early wide-body airplanes include the following: Airbus A300; Boeing 747-100/-200/-300/SP; Lockheed L-1011; and Douglas DC-10.

[6] Current airplanes include the following: Airbus A300-600, A310, A320/319/321, A330 and A340; Avro RJ-70/-85/-100; BAE Systems 146; Boeing 717, B-737-300/-400/-500/-600/-700/-800/-900, B-747-400, B-757, B-767 and B-777; Fokker 70 and Fokker 100; and McDonnell Douglas MD-11 and MD-80/-90.

Source: The Boeing Co.

Twelve airplanes (17 percent) were destroyed in hard-landing accidents, and 47 airplanes (67 percent) were substantially damaged. Eleven airplanes received minor damage in hard landings during the period.

'Hard Landing' Not Well Defined

There appears to be no universal definition of *hard landing*. The International Civil Aviation Organization (ICAO) assigns event code 263 for the reporting of hard landings by member states but has no formal definition of the term.[4]

Milton Wiley, an ICAO technical officer, said that the ICAO accident and incident database (ADREP) includes hard landings in the category of events involving *abnormal runway contact*.[5]

"There is no hard and fast rule for reporting a hard landing," Wiley said "It really is in the eyes of the beholder."

The Transportation Safety Board of Canada and the French Bureau d'Enquêtes et d'Analyses pour la Sécurité de L'Aviation Civile are among accident-investigation authorities that use the ICAO event code but have no formal definition of hard landing.[6,7]

In the United States, the National Transportation Safety Board (NTSB) coding manual defines hard landing as "stalling onto or flying into a runway or other intended landing area with abnormally high vertical speed."[8]

Jacques Leborgne, senior director of structure engineering for Airbus, defined a hard landing as one that exceeds the limit landing loads specified in European Joint Airworthiness Requirements (JARs) and U.S. Federal Aviation Regulations (FARs) transport category airplane certification requirements.[9]

Landing Gear Absorbs the Shock

An airplane's kinetic energy (vertical load, side load, back load, etc.) on touchdown is dissipated by the landing gear.[10] The energy is dissipated primarily by the landing-gear struts. A strut typically is filled with oil that is forced at a controlled rate through an orifice as the strut is compressed on touchdown.

Under normal conditions, landing-gear load is affected directly by the airplane's gross weight. As gross weight increases, the required approach speed increases. If the glide path is the same (e.g., an approach on a three-degree glideslope), the higher approach speed results in a higher descent rate and, thus, a higher load on the landing gear. The load placed on the landing gear increases as the square of any increase in the vertical rate of descent. For example, a 20 percent increase in vertical rate of descent (i.e., descent rate times 1.2) increases the landing load factor by 44 percent (1.2 squared = 1.44).[11]

Landing gear are either *overdesigned* to withstand landing loads greater than those required for certification or incorporate fuse pins, which ensure that the landing gear breaks from the wing when loads exceed the design limit. Loads not dissipated by the landing gear typically are transferred to the landing-gear support structure, wing spars, fuselage structure and skin.

During the certification of transport category airplanes, the European Joint Aviation Authorities (JAA)[12] and the U.S. Federal Aviation Administration (FAA)[13] require a test of "reserve energy absorption," in which the landing gear must withstand touchdown at a descent rate of 12 feet per second with the airplane at the design landing weight and with lift not greater than weight on impact (i.e., with a vertical acceleration of 1.0 g [standard gravitational acceleration]).

JAA and FAA also require that the main landing gear on transport category airplanes with 10 or more passenger seats be designed so that an overload failure is not likely to result in enough fuel spillage to create a fire hazard.

Is the Landing 'Hard' or Just 'Firm'?

Early in their careers, pilots typically strive to conduct smooth touchdowns, in which the transition from flight to the landing roll is barely noticeable. A smooth touchdown typically is accomplished by extending the flare to allow airspeed to decrease to just above the point of a stall.[14]

The loss of airspeed during an extended flare, however, can result in a sudden, rapid loss of altitude and a hard landing.[15] A normal flare that results in a smooth touchdown in the runway touchdown zone generally is desirable when flying turbine-powered airplanes. Nevertheless, a firm touchdown might be appropriate in specific conditions (e.g., crosswinds, a short runway and/or a runway that is wet or contaminated with standing water, snow, slush or ice).

The major advantage of a firm landing is the reduced risk of a runway overrun. Deliberately and positively landing the airplane in the runway touchdown zone not only precludes a "dropped-in touchdown" but promptly gets the weight of the airplane on the main wheels, thus improving the effectiveness of wheel braking. A firm landing also allows the pilot to fly the nosewheel onto the runway, reducing angle-of-attack and lift, and further improving the effectiveness of wheel braking.

As a report by a Boeing 737 captain to the U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) indicates, however, the difference between a firm landing and a hard landing might not be clearly discernable.[16]

The captain said that the visual approach and the landing flare appeared to be normal, but the airplane bounced high on touchdown. While airborne, the airplane pitched nose-up, and both the captain and the first officer applied nose-down pitch control. The captain said that the second touchdown and rollout were "without incident."

"After securing the aircraft at the gate, I asked the [first officer] if I should write up a hard landing," he said. "We concurred that although the landing wasn't good for my ego, it did not qualify as a hard landing."

A flight attendant who was in the aft jump seat during the landing, told the captain that she did not

The loss of airspeed during an extended flare can result in a sudden, rapid loss of altitude and a hard landing.

believe that the landing was hard or had resulted in a tail strike. The captain found no visible damage during a postflight inspection of the airplane. No damage was found during preflight inspections by another flight crew that conducted two subsequent flights in the airplane. Nevertheless, a routine overnight maintenance inspection revealed an eight-inch (20-centimeter) crack in the fuselage skin forward of the airplane's tail skid.[17]

Different perceptions of a landing by the flight crew and a flight attendant were the subject of an ASRS report filed by a Boeing MD-11 first officer.

"We landed [with an] approximately five-knot tail wind," the first officer said. "The landing was judged to be firm but not hard. Upon return [to the base airport] 30 hours later, a flight attendant announced that she had a sore back due to the hard landing. It was news to us, and we did not feel that it was a hard landing."[18]

An Airbus A320 captain reported to ASRS that after a landing that he perceived as "more firm than normal," a deplaning passenger said that her neck was sore from the landing. The captain directed the passenger to a gate agent. When he later went to the gate area to check on the passenger, he found that she was being attended by two paramedics.

"She seemed fine and in good spirits, and commented that this was a hard landing but that she had been in harder landings," the captain said. "I said, 'Yes, madam, me too.' One of the paramedics asked about the landing, and I told him it was a little harder than usual but, in my opinion, not injury-producing."

> **"The pilot must make the decision as to whether a structural inspection is necessary."**

The captain said that his company later told him that other passengers had complained about the hard landing.[19]

Pilots Call for Inspections

In a report on a hard-landing accident in Lilongwe, Malawi, on April 5, 1997, the U.K. Air Accidents Investigation Branch (AAIB) said that "maintenance manuals consistently state that the pilot must make the decision as to whether a structural inspection is necessary."[20]

The accident involved a B-747-400 that was flown into a rain shower during a visual approach. The report said that the captain (the pilot flying) declined the first officer's offer to activate his windshield wipers because he previously had found the movement of the wipers and the noise produced by the wipers to be distracting.

"It is probable that the visual references used by the captain during the landing phase were distorted by the presence of water on the [windshield]," the report said. "The distortion would have been significantly reduced by the use of the [windshield] wipers."

The captain did not flare the airplane for landing. The airplane, which was near its maximum gross weight, bounced on touchdown. The first officer observed that the airplane was airborne over the right side of the runway, called for a go-around and applied full power.

The flight crew conducted the go-around and subsequent landing without further incident. While taxiing the airplane to the gate, the flight crew was told by the station maintenance manager (SMM), who had been seated in the cabin, that 12 passenger-service units and an over-aisle video-display screen had broken loose. The captain told the SMM to conduct a hard-landing inspection.

The first officer and the SMM conducted walk-around visual inspections of the airplane but found no damage.

"During his initial 'walk around' the exterior of the aircraft, the SMM looked, from experience, for signs of bursting or over-pressuring of [tires], integrity of the main [landing gear] and body landing gear, the airframe in general and engine-alignment marks," the report said. "There were no signs of structural damage."

The SMM then conducted the "Phase I" hard-landing inspection procedures specified in the aircraft maintenance manual (AMM).

"The Phase I inspection covers four sheets from the maintenance manual and directs attention primarily at the landing gear, the engine nacelles and the engine attachments to the wing," the report said. "In addition, items are included for the wing-leading-edge fairings, the trailing-edge-flap mechanisms, the horizontal stabilizer fuel tank and the APU [auxiliary power unit] supports. … In addition to the Phase I items specified, he performed a number of checks based on his experience, such as opening and closing all the exterior cabin [doors] and baggage doors on the aircraft, looking for any signs of misalignment or mismatch."

The six-hour inspection revealed no indication of structural damage. Thus, the SMM was not required to proceed with the more detailed Phase II hard-landing inspection specified by the AMM. Nevertheless, the SMM filed an Acceptable Deferred Defect report, requiring the airplane to receive a Phase I inspection upon its return to London, England.

"During the repeat Phase I inspection at London Gatwick [Airport], signs of fuselage skin damage were noted just aft of the wing … with substantial areas of 'quilting' and 'rippling' of the skin panels," the report said.

The subsequent Phase II inspection revealed structural damage. After extensive repairs were performed, the airplane was returned to service on June 1, 1997.

The report said that the airplane-condition monitoring system recorded a vertical acceleration of 2.8 g and a sink rate of 1,070 feet per minute during the initial touchdown in Malawi. The data were not available to the flight crew or the SMM. After the accident, the airline programmed the airborne communications addressing and reporting system equipment aboard all airplanes in the fleet to provide printouts for the flight crew of vertical accelerations of 1.8 g or more recorded during touchdown.

Based on the accident investigation, AAIB recommended that the U.K. Civil Aviation Authority (CAA) consider "methods for quantifying the severity of landings based on aircraft parameters recorded at touchdown" to aid flight crews in determining the need for hard-landing inspections.

The recommendation was not accepted. In response, the U.K. CAA said, "Reliance on flight crew judgment is the widely accepted and proven method of determining whether a hard landing has occurred. In the subject incident, the flight crew identified correctly that a hard landing had occurred and called properly for a hard landing inspection. The [CAA] therefore believes that mandating the fitment of equipment that would allow frequent access to flight recorder data which would aid flight crew judgment that a hard landing has occurred is not justified."[21]

"The flight data recorder does not appear to be designed for recording landing quality."

Backup Data Help Identify Problems

In an ASRS report, the first officer of a Douglas DC-9 freighter said that his company was checking recorded flight data to determine whether he had been involved in an unreported hard landing in the airplane.

"No landing I was involved in [with] this aircraft could be reasonably classified as 'hard,'" the first officer said. "[My company] does not define 'hard landing' in their general ops [operations] manual or aircraft ops manual, nor do they train their [flight crews] in recognition or reporting of same. I am further concerned that [the company] is removing the aircraft's flight data recorder to investigate this matter. The flight data recorder does not appear to be designed for recording landing quality."[22]

Airbus and Boeing publish vertical-acceleration "thresholds" that, when recorded by flight-data-monitoring equipment, should prompt a hard-landing conditional-maintenance inspection.

Airbus AMMs recommend that a hard-landing inspection be performed when the flight crew reports a hard landing and the digital flight data recorder (DFDR), or equivalent data-monitoring unit, indicates that the vertical speed on touchdown exceeded 10 feet per second and/or vertical acceleration exceeded a specific value, based on airplane type and landing weight. The vertical-acceleration threshold for an A340-300, for example, is 1.75 g at less than maximum landing weight.[23]

The vertical-acceleration thresholds in Boeing AMMs vary from 1.8 g for the B-747 models to 2.2 g for the B-737 models (when recorded by DFDRs that record 16 samples per second; different values are published for DFDRs with different sampling rates).[24]

Boeing recommends, however, that because of limitations of the equipment that measures vertical acceleration, the recorded flight data be used only to cross-check flight crew reports of hard landings.

"There are inherent inaccuracies in using vertical-acceleration-recorder — g-meter or accelerometer — data to identify hard landings," said Capt. David Carbaugh, chief pilot for flight operations safety at Boeing Commercial Airplanes.[25] "Vertical-acceleration recorders normally are positioned in the aircraft to sense in-air accelerations. They can be used to record touchdown accelerations, also; however, because of their location in the airplane and errors due to roll and other factors, they can be inaccurate up to 0.4 g."

"When you smash one on, you know it."

Recorded vertical accelerations vary both in duration and magnitude and are affected by the airplane's weight, center of gravity, motion (e.g., sink rate, forward/side velocity and roll/pitch/yaw attitude), external forces (e.g., gust loads) and structural dynamics (e.g., airframe vibrations and harmonics).

"Using vertical-acceleration values as the sole criterion for initiating unscheduled inspections is generally not advisable because of the location and design considerations of the FDRs and accelerometers," Boeing said.[26] "In most instances, there is no absolute way of knowing whether the recorded accelerations are a minimum [value], maximum [value] or some intermediate value relative to the entire airframe structure."

Boeing recommends that conditional maintenance inspection be performed whenever a flight crew reports a hard landing, even if the recorded vertical acceleration did not exceed the threshold cited in the AMM.

"Service experience indicates that most flight crews report a hard landing when the sink rate exceeds approximately four feet per second," Boeing said. "Past experience also indicates that the flight crew's determination of a hard landing is the most reliable criterion because of the difficulty in interpreting recorded acceleration values."

Landing 'Like a Ton of Bricks'

Neither Airbus nor Boeing provides specific guidance for flight crews on identifying a hard landing. Carbaugh said that a landing of sufficient impact to cause structural damage should be obvious to the flight crew.

"We don't spell out exactly what a hard landing is," he said. "If I had to define it, I would say that it is a landing that the pilot believes had the potential to cause structural damage and requires a maintenance inspection.

"When you smash one on, you know it. Nobody on that airplane is not going to know that you had a hard landing. A hard landing is when you land like a ton of bricks. Pilots are supposed to write up hard landings; for the safety of the passengers and the crewmembers to come, they should at least have the airplane inspected."

Leborgne said that the preflight inspection procedures and postflight inspection procedures recommended by Airbus do not include specific information on checking for hard-landing damage.

Carbaugh said that airline pilots typically do not conduct postflight inspections and that a postflight inspection might not reveal signs of a hard landing. Deformation of a tail skid from a tail strike, distortion of the "doghouse" (the boxlike structure that supports the nose gear) from a hard nose gear touchdown, fuel leaks, popped rivets or cracks or wrinkling of fuselage skin might be apparent. Other damage, such as a strut that is cracked but not leaking, might not be apparent.

"You're not going to crawl up and down the axle and take a look at that stuff," he said. "Maintenance personnel will do that kind of inspection."

John Ferrante, manager of line maintenance for American Airlines, said that he would not recommend that flight crews perform a postflight inspection to confirm whether or not a hard landing occurred.[27]

"Pilots are not trained to do that," he said. "In some cases, they would not have access to areas that might be damaged. For example, if the airplane was landed hard on the nose gear, the crown skin, which is above and behind the cockpit, might show signs of structural damage. Probably the best indication to pilots of a possible hard landing is the airplane's sink rate on touchdown. If there is any question about it, we might download the recorded data to help us determine whether an inspection is in order."

Ferrante said that the economic consequences to an airline from a hard landing depend on many factors, such as labor costs and down time on the airplane. He said that a Phase I visual inspection typically requires 1 1/2 hours to two hours and that the more-detailed Phase II inspection requires about eight hours, plus any time required to repair damage.

Carbaugh said that the cost to repair hard-landing damage to an airplane can amount to millions of dollars. Some older airplanes have been "written off" (permanently removed from service) after hard landings.

"Spars, landing-gear components and other parts were broken, and the expense to repair the older airplanes was more than the expense to write them off," he said. "The insurance companies preferred to pay the two million to write them off than the three million to fix them."

Stabilized Approach Reduces Risk

Safety specialists agree that conducting a stabilized approach significantly reduces the risk of a hard landing.

"Hard landings usually result from nonstabilized approaches conducted in difficult situations," Carbaugh said. "Crews need to know that just prior to touchdown, the go-around option is there for them. If things are not going well, and you're not stabilized, going around is the right thing to do."

Table 2 (page 8) shows elements of a stabilized approach that were recommended by the Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force.[28] The task force said that the flight crew should conduct a go-around if an approach becomes unstabilized below 1,000 feet above airport elevation in instrument meteorological conditions or below 500 feet above airport elevation in visual meteorological conditions (VMC).

An A300 captain's failure to conduct a stabilized approach or a go-around was cited by NTSB in its report on an accident that occurred in St. John's, Antigua, on Feb. 6, 1997.[29] The flight crew was conducting a nonprecision approach in daytime VMC when they established visual contact with the runway 1,000 feet above ground level (AGL) and observed that the airplane was "slightly high." The crew said that at 500 feet AGL, the airplane was "in the slot" (on the proper glide path) but 15 knots above the target approach speed. The engines were producing minimum thrust.

The captain (the pilot flying) increased the pitch attitude from 0.5 degree nose-down to nine degrees nose-up. The descent rate decreased from 1,700 feet per minute to 1,000 feet per minute, and the glide path angle decreased from 5.8 degrees to 2.7 degrees. The captain said that he began the flare about 30 feet AGL, then "deepened" the flare just prior to touchdown to "cushion the landing."

The airplane bounced. Pitch attitude was increased to 11 degrees, and the airplane's tail struck the runway. Damage included five panels on the lower fuselage that were destroyed, three broken landing-gear struts, a twisted floor beam and buckled or sheared frames and stringers in the tail area. None of the 170 occupants was injured.

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At the time of the accident, the airline's operating manual included techniques for conducting a stabilized approach but did not include information on what flight crews should do if an ap-

Table 2
Recommended Elements of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met*:

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1, November 2000)

proach became unstabilized. The report said that the absence of this guidance was a factor that contributed to the accident. After the accident, the airline told NTSB that it adopted a recommendation by the FSF ALAR Task Force to declare and support a no-fault go-around policy.

Apply Wind-correction Factors

Typical approach technique is to arrive 50 feet over the runway threshold — as measured from the airplane's main landing gear — at landing reference speed (V_{REF} — 1.3 times the airplane's stall speed in landing configuration) plus a head wind-correction factor.

Common wind-correction factors are five knots when the winds are calm or light, or one-half the wind velocity plus all of the gust velocity; the wind-correction factor should not exceed 20 knots. For example, with winds at 10 knots, gusting to 20 knots, the target approach speed would be V_{REF} plus 15 knots. The correction factor for wind velocity (five knots in the example) would be bled off during the flare, while the gust-correction factor (10 knots) would be carried onto the runway.[30]

The wind-correction factors are for the head wind components of the steady-state winds and gusts. The correction factors are provided by some flight management systems or by calculations based on the crosswind table provided in the airplane flight manual. A common rule of thumb for V_{REF} corrections is to add 50 percent of the velocity of a direct head wind, 35 percent of the velocity of a 45-degree crosswind, and none of the velocity of a 90-degree crosswind, and to interpolate between these values.[31]

A Lockheed L-1011 captain's failure to maintain the proper approach speed was cited by NTSB in a hard-landing accident that occurred in Maui, Hawaii, U.S., on May 9, 2000.[32] The surface winds were reported at 22 knots, gusting to 27 knots. The accident report said that V_{REF} for the airplane's landing weight was 138 knots and that with wind-correction factors, the proper target approach speed was 150 knots. During the last 10 seconds of the approach, the airplane's indicated airspeed decreased from 143 knots to 130 knots.

All three flight crewmembers said that the touchdown was harder than normal but not one that they would classify as a hard landing. Several flight attendants said that two ceiling panels dislodged when the airplane "slammed down" onto the runway. During a postflight inspection of the airplane, the flight engineer found that the lower rear fuselage was damaged. A subsequent maintenance inspection revealed damage, consistent with a tail strike, to the pressure bulkhead and several bell frames and stringers in the aft fuselage.

Cope With Crosswinds

Adverse wind conditions — crosswinds, tail winds, wind shear, etc. — can cause an approach to become unstabilized. Rapid and large flight-control movements in reaction to gusts increase the risks of a hard landing and of striking a wing tip or an engine nacelle against the runway.[33]

JAA and FAA transport category airplane certification standards require a demonstration of safe controllability characteristics and handling characteristics during a landing on a dry runway with a 90-degree crosswind component of at least 20 knots or equal to 0.2 V_{SO} (the airplane's stall speed or minimum steady flight speed in landing configuration), whichever is greater. The demonstration does not have to be conducted with a crosswind component of more than 25 knots, however.

Nevertheless, most large jets have demonstrated crosswind components that are greater than 25 knots. Examples include: 33 knots for the A320-100/200; 32 knots for the B-747SP; and 35 knots for the MD-11.

Demonstrated crosswind components generally are advisory, not limiting. Some aircraft operators prohibit flight crews from conducting a landing if wind conditions exceed the airplane's demonstrated crosswind component. FAA prohibits air carrier first officers with fewer than 100 flight hours in type from landing with a crosswind component of 15 knots or more unless they are flying with a check pilot.[34] In the absence of such prohibitions, flight crews can conduct a landing if wind conditions exceed the airplane's demonstrated crosswind component when they believe it is safe to do so.

Crab or Slip

Generally, flight crews use one of two techniques to land with a crosswind.

The "crab/de-crab" technique involves establishing a wings-level crab angle on final approach that is sufficient to track the extended runway centerline (Figure 1, page 10). About 100 feet AGL, downwind rudder is applied to de-crab and align the airplane with the runway centerline, and upwind aileron is applied to prevent drift or to keep the wings level if the airplane has underwing-mounted engines or long wings. This technique results in the airplane touching down simultaneously on both main landing gear with the airplane aligned with the runway centerline.

The other technique is to establish a steady sideslip (forward slip) on final approach by applying downwind rudder to align the airplane with the runway centerline and upwind aileron to lower the wing into the wind to prevent drift. The upwind wheel(s) should touch down before the downwind wheel(s) touch down.

If the airport has more than one runway, the flight crew should land the airplane on the runway that has the most favorable wind conditions. Nevertheless, factors such as airport maintenance or noise-abatement procedures sometimes preclude this.

Demonstrated crosswind components generally are advisory, not limiting.

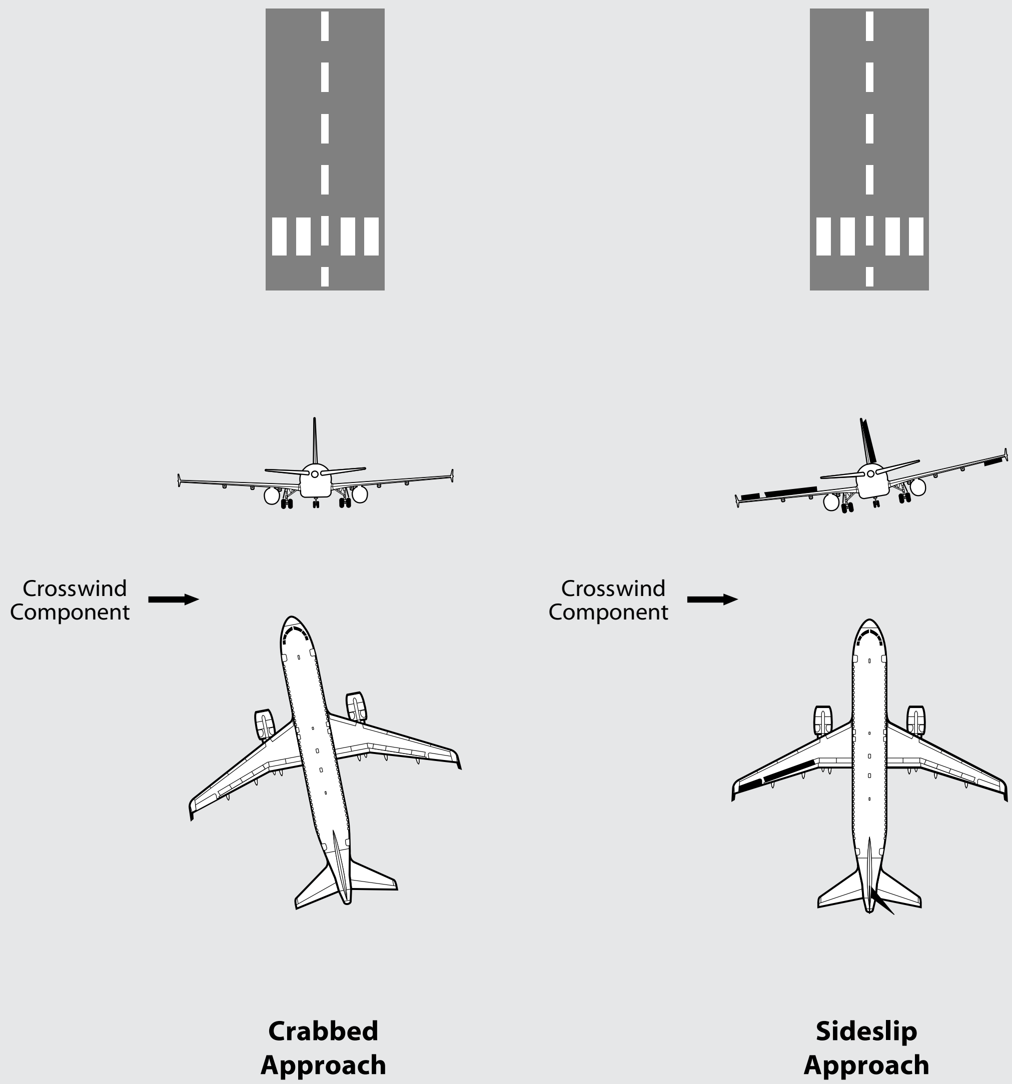
ICAO recommends that the crosswind component, including gusts, should not exceed 15 knots on the designated landing runway.[35] Adherence to this recommendation varies among ICAO member states. At more than 300 air carrier airports, designation of the landing runway might be based on noise-abatement criteria rather than wind direction.[36]

The runway-allocation system in effect at Schiphol Airport and a B-757 flight crew's failure to calculate the crosswind component were among causal factors cited by the Dutch Transport Safety Board (TSB) in the Dec. 24, 1997, hard-landing accident in Amsterdam, Netherlands.[37]

Surface winds were reported from 230 degrees at 33 knots, gusting to 45 knots, when the flight crew conducted an approach to Runway 19R. The report said that the airport's nighttime preferential-runway-allocation system precluded the use of Runway 24.

When the captain (the pilot flying) disengaged the autopilot about 100 feet AGL, the airplane yawed five degrees right and began to drift left. The captain made control inputs to correct the

Figure 1
Common Techniques for Crosswind landings



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

drift. Just before touchdown, a gust caused an increase in indicated airspeed and nose-up pitch attitude; the captain applied nose-down pitch control and reduced power. The airplane had a crab angle of eight degrees when the left-main landing gear and the nose landing gear touched down hard. The nose landing gear collapsed, and the airplane slid about 3,000 meters (9,843 feet) before stopping off the side of the runway. Three of the 213 occupants received minor injuries while evacuating the airplane.

The Dutch TSB, in its final report on the accident, said that the following were causal factors:

- "[The] runway-allocation system at Schiphol Airport resulted in strong crosswind conditions for the landing runway in use;
- "By the omission to state clear and definite crosswind limitations in the [airline's] operating manual, a defense barrier against unsafe operations was [absent];

- "Non-calculation and/or discussion of [the] crosswind component resulted in continuing the approach in adverse weather conditions;
- "Disconnect of the autopilot in the 'align' mode under the existing wind conditions resulted in an out-of-trim condition of the aircraft;
- "The low altitude of the autopilot disconnect in relation to the existing wind conditions allowed the pilot insufficient time to gain complete control of the aircraft, which resulted in a hard, traversing landing; [and,]
- "The hard nosewheel touchdown, exceeding the certified design limits, resulted in a failure of the nose-gear [structure]."

Beware Tricky Tail Winds

Tail winds are especially challenging for conducting a stabilized approach. Neither Airbus nor Boeing publish V_{REF} correction factors for tail winds. Because of the increased groundspeed caused by a tail wind, rate of descent must be increased to maintain the proper glide path.[38]

Figure 2 (page 12) shows the rates of descent required to maintain a three-degree glideslope at a constant approach speed of 145 knots with tail winds of five knots, 10 knots and 15 knots at various altitudes. (Wind speed normally decreases with altitude and typically is measured at 33 feet AGL.)

To maintain the proper approach speed while increasing rate of descent, thrust must be reduced. If a go-around is required, precious seconds might be lost as the engines accelerate; the airplane would continue to descend and might touch down on the runway before the engines produce enough thrust to enable a climb.

JAA and FAA require that the "effects of increased [runway] contact speed must be investigated" only for landings with tail winds exceeding 10 knots. Several airliners have been certified for operation with a 15-knot tail wind component.

ICAO recommends that the tail wind component, including gusts, should not exceed five knots on the designated landing runway. Again, adherence to this recommendation varies among member states. In the United States, for example, FAA sets the tail-wind-component limit for clear, dry runways at five knots; the limit increases to seven knots if anemometers are installed near the runway touchdown zone. FAA allows no tail wind component if the runway is not clear and dry.[39]

When in Doubt, Go Around

Several hard-landing accidents have been attributed to the flight crew's failure to conduct a go-around. Some of the accidents occurred when the approach became unstabilized in the flare.

When is it too late in an approach to conduct a go-around?

"Generally, depending on the airplane model you're flying, when you deploy the thrust reversers or ground spoilers — you're committed to land," Carbaugh said. "Sometimes, a last-second go-around — when you're about to drop it in — won't keep you from hitting the runway, but it will cushion the blow, and you can continue the go-around."

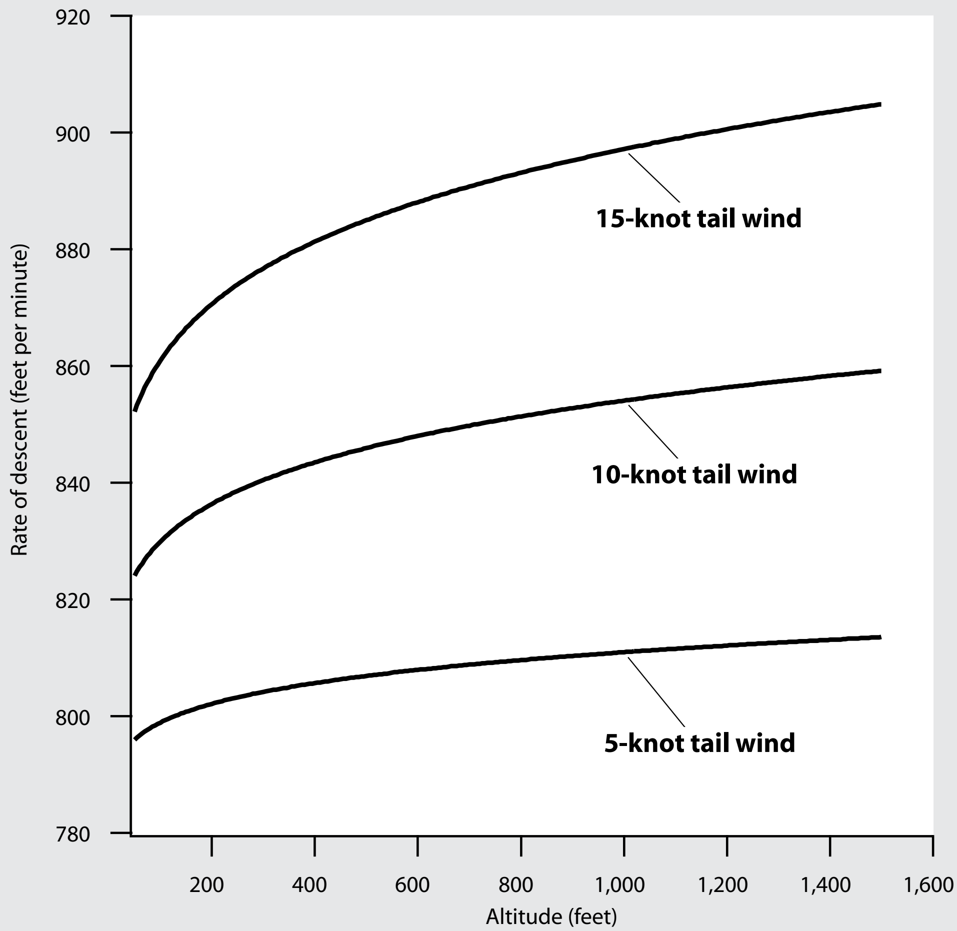
An ASRS report by an A320 captain discussed a late go-around that resulted in runway contact. The flight crew was following a B-767 on approach, and the captain (the pilot flying) disconnected the autopilot about 800 feet AGL to fly the airplane slightly above the instrument landing system (ILS) glideslope. The captain said that about 30 feet AGL, the A320 encountered wake turbulence from the B-767 and began to sink rapidly. The A320 crew initiated a go-around. As the engines accelerated, the airplane touched down with a high sink rate.

The crew completed the go-around and landed the airplane without further incident. None of the occupants was injured, and a postflight inspection revealed no airplane damage.[40]

An MD-11 captain's failure to conduct a go-around when an

Some of the accidents occurred when the approach became unstabilized in the flare.

Figure 2
Examples of Descent Rates Required to Maintain Glideslope With a Tail Wind*



* Examples assume a constant approach speed of 145 knots, a three-degree glideslope and tail wind velocities measured at 33 feet (10 meters) above ground level.

Source: Gerard W.H. Van Es and Arun K. Karwal, from "Safety of Tailwind Operations" in *Toward a Safer Europe: Proceedings of the 13th Annual European Aviation Safety Seminar*; Alexandria, Virginia, U.S.: Flight Safety Foundation, 2001.

approach became unstabilized during the flare was cited by NTSB in its report on an accident that occurred at Newark (New Jersey, U.S.) International Airport on July 31, 1997.[41]

The airplane was flown under the provisions of its minimum equipment list with an inoperative engine-thrust reverser. The report said that this — together with a miscalculation by the crew of required landing distance and recent malfunctions of the airplane's autobrake system — influenced the flight crew's concern about the landing and created "a sense of urgency to touch down early and initiate maximum braking immediately."

The crew conducted an ILS approach to Runway 22R, which was 8,200 feet (2,501 meters) long, with 6,860 feet (2,092 meters) of runway remaining after the point at which the ILS glideslope intersects the runway. The crew had calculated incorrectly that 800 feet (244 meters) of runway would remain after the airplane was brought to a stop using maximum autobraking. The report said that the correct figure was 2,730 feet (841 meters).

The weather was clear and surface winds were light when the captain hand-flew the nighttime approach. The approach was stabilized; the airplane was in landing configuration and on the ILS glideslope and localizer, and airspeed was one knot higher than the target approach speed (157 knots). The flare was begun properly; the airplane was about 37 feet above the runway when the captain began increasing the nose-up pitch attitude about 2.5 degrees.

The report described what happened next as a "classic pilot-induced oscillation." Instead of maintaining a constant pitch attitude, as recommended by the MD-11 flight manual, the captain rapidly applied nose-down pitch control. Both pilots felt the airplane's sink rate increase.

The report said that with one second remaining before touchdown, the captain had three options: accept the sink rate and the resulting hard landing; attempt to salvage the landing by increasing thrust and nose-up pitch; or conduct a go-around.

The report said that a go-around would have prevented the accident; the captain chose to try to salvage the landing. He applied nose-up pitch control and increased power from near-flight-idle thrust to near-takeoff thrust. The sink rate had just begun to decrease when the airplane touched down on the runway. The report said that the captain moved the control column full forward in an attempt to keep the airplane on the runway, but the airplane bounced back into the air, reaching a maximum height of five feet.

The airplane was airborne about two seconds. The captain pulled the control column back in an effort to soften the impact; he also applied left rudder and right aileron (the report said that investigators could not determine why he did this). Vertical speed was approximately 13.5 feet per second when the right-main landing gear struck the runway.

"The energy transmitted into the right-main landing gear during the second touchdown was 3.2 times greater than the MD-11's maximum certificated landing energy and was sufficient to fully compress ('bottom') the right-main landing-gear strut and cause structural failure of the right-wing rear spar," the report said.

The right wing separated, a fuel-fed fire ignited, and the airplane slowly rolled right. The airplane slid on the runway and came to a stop inverted 5,126 feet (1,563 meters) from the runway threshold.

The five occupants — the captain, first officer, two passengers (airline employees) and a jump-seat passenger (a pilot for another airline) — received minor injuries. The airplane — valued at US$112 million — and the cargo were destroyed by the impact and postaccident fire.

The report said that the probable causes of the accident were "the captain's overcontrol of the airplane during the landing and his failure to execute a go-around from a destabilized flare."

An approach can become unstabilized if the pilot flying applies stabilizer trim during the flare. Boeing said that the pilot can lose the "feel" of the elevator while the trim system is operating. If excessive nose-up trim is applied, the airplane will pitch up and touch down hard on the main landing gear or on the main landing gear and nose landing gear.[42]

"Flight crews should trim the airplane during the approach but not in the flare," Boeing said.

Be Prepared for a Bounce

The FSF ALAR Task Force said that bounced landings usually result from loss of visual references, excessive sink rate, late initiation of the flare, excessive airspeed or a power setting on touchdown that prevents automatic extension of ground spoilers.[43]

The task force said that to recover from a light bounce — five feet or less — the flight crew should do the following:

- "Maintain or regain a normal landing pitch attitude (do not increase pitch attitude because this could lead to a tail strike);
- "Continue the landing;
- "Use power as required to soften the second touchdown; and,
- "Be aware of the increased landing distance."

An approach can become unstabilized if the pilot flying applies stabilizer trim during the flare.

If the airplane bounces more than five feet, a go-around should be conducted because insufficient runway might remain for a safe landing, the task force said. The following go-around procedure is recommended:

- "Maintain or establish a normal landing pitch attitude;
- "[Activate] the go-around levers/switches and [advance] the throttle levers to the go-around thrust position;
- "Maintain the landing flaps configuration or set a different configuration, as required by the aircraft operating manual (AOM)/quick reference handbook (QRH);
- "Be prepared for a second touchdown;
- "Be alert to apply forward pressure on the control column and reset the pitch trim as the engines spool up (particularly with underwing-mounted engines);
- "When safely established in the go-around and when no risk remains of touchdown (steady, positive rate of climb), follow normal go-around procedures; and,
- "Re-engage automation, as desired, to reduce workload."

Fly the Nose Gear Onto the Runway

Transport category airplanes are designed with enough nose-down elevator authority to control the airplane's tendency to pitch up when maximum power is applied for a go-around. The nose-down elevator authority is sufficient to cause structural damage if the airplane is derotated rapidly after the main landing gear touch down and the nose landing gear strikes the runway.[44]

Data recorded by Boeing during normal landings and during landings in which structural damage was caused by hard nose-landing-gear touchdowns show that the latter involved application of nose-down pitch control (Figure 3).

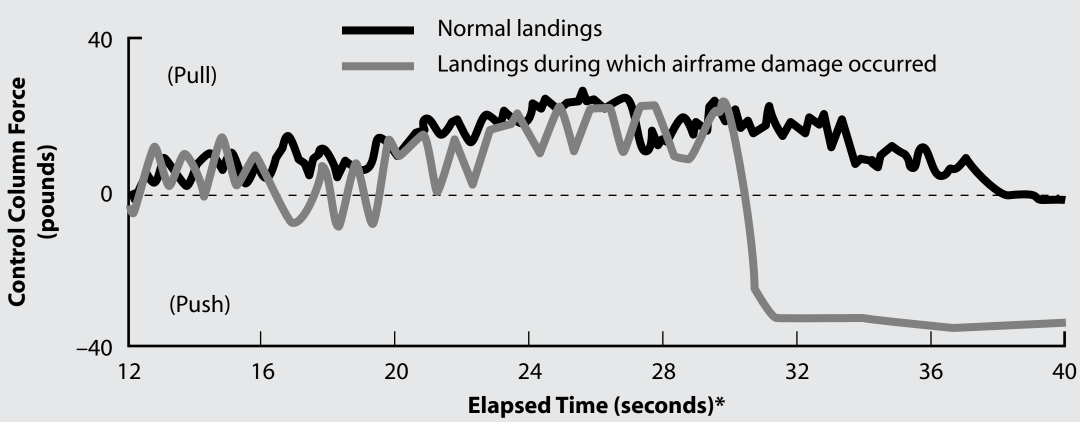
After the main landing gear touch down, the flight crew should relax aft pressure on the control column and fly the nose landing gear onto the runway. Boeing said that control-column movement forward of the neutral position should not be required.[45]

The nose should not be lowered rapidly in an effort to improve landing performance or directional control; the rudder has enough authority to maintain directional control during this phase of the landing. Similarly, pushing forward on the control column after the nose landing gear is on the runway does not improve the effectiveness of nosewheel steering and, by reducing the weight on the main landing gear, could reduce the effectiveness of wheel braking.[46]

The U.K. AAIB said that a hard nose-landing-gear touchdown that resulted in substantial damage to a Boeing 757 resulted, in part, from the captain's apparent development of a habit of applying full-nose-down elevator control on landing.[47] The accident occurred in Gibraltar, U.K., on May 22, 2002.

Winds were from 260 degrees at 23 knots, and the flight crew was conducting a visual approach to Runway 27. The report said that the approach and flare were normal, but immediately after the main wheels touched down on the runway, the airplane's nose pitched down rapidly and the nosewheel struck the runway. None of the 175 occupants was injured, but a postflight inspection of the airplane revealed that the forward fuselage in the area of the nosewheel was damaged

Figure 3
Control-column Movements Recorded During Normal Landings and Landings Involving Airframe Damage



* Landings are positioned so that all reach zero feet radio altitude at the same elapsed time (28.5 seconds).

Source: The Boeing Co.

substantially.

Recorded flight data showed that the captain had applied full-down elevator control during landings for several months before the accident.

"The [captain] was unaware that he had developed the regular use of full nose-down elevator on landing, although he remembers using full-forward stick occasionally when landing in wet or slippery conditions in the belief that the technique would improve braking and control effectiveness," the report said. "It is possible that repetition of the control-input sequence in the context of landing had established a habit."

Avoid the Shock

In summary, a hard landing can be avoided by conducting a stabilized approach by using proper technique for handling adverse wind conditions and for conducting the flare and derotation — and, most importantly, by going around if the approach becomes unstable or if the airplane bounces more than five feet on touchdown.

If there is any reason for the flight crew to believe that the landing was hard — or firmer than normal — a hard-landing report should be filed so that a conditional maintenance inspection is performed to ensure the airplane's airworthiness. ■

Notes

1. Boeing Commercial Airplanes. *Statistical Summary of Commercial Jet Airplane Accidents, Worldwide Operations 1959–2002*.
2. Controlled flight into terrain (CFIT) occurs when an airworthy aircraft under the control of the flight crew is flown unintentionally into terrain, obstacles or water, usually with no prior awareness by the crew. This type of accident can occur during most phases of flight, but CFIT is more common during the approach-and-landing phase, which begins when an airworthy aircraft under the control of the flight crew descends below 5,000 feet above ground level (AGL) with the intention to conduct an approach and ends when the landing is complete or the flight crew flies the aircraft above 5,000 feet AGL en route to another airport.
3. The accidents were reported by various sources to have involved hard landings or hard touchdowns by transport category, turbojet airplanes from 1996 through 2002.
4. International Civil Aviation Organization (ICAO). *Accident/Incident Reporting Manual*. Appendix 4, *Codes for Events and Phases*.
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6. Stonier, John; Transportation Safety Board of Canada. Telephone interview by Lacagnina, Mark. Alexandria, Virginia, U.S. July 16, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S.
7. Guilldou, Alain; chief of the Division of Information and Communication, Bureau d'Enquêtes et d'Analyses pour la Sécurité de L'Aviation Civile. E-mail communication with Lacagnina, Mark. Alexandria, Virginia, U.S. July 29, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S.
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13. U.S. Federal Aviation Administration (FAA). Federal Aviation Regulations (FARs) Part 25, *Airworthiness Standards: Transport Category Airplanes*. Subpart C, *Structure*. Subpart D, *Design and Construction*.
14. Blake, Walter; Elliot, Richard. "The Last Two Minutes." *Boeing Airliner* (January–March 1991).
15. The Boeing Co. *Boeing All Model FCTM* (Flight Crew Training Manual). Draft, 2004.
16. The U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) is a confidential incident-reporting system. The ASRS Program Overview said, "Pilots, air traffic controllers, flight attendants, mechanics, ground personnel and others involved in aviation operations submit reports to the ASRS when they are involved in, or observe, an incident or situation in which aviation safety was compromised. … ASRS de-identifies reports before entering them into the incident database. All personal and organizational names are removed. Dates, times and related information, which could be used to infer an identity, are either generalized or eliminated."

   ASRS acknowledges that its data have certain limitations. ASRS *Directline* (December 1998) said, "Reporters to ASRS may introduce biases that result from a greater tendency to report serious events than minor ones; from organizational and geographic influences; and from many other factors. All of these potential influences reduce the confidence that can be attached to statistical findings based on ASRS data. However, the proportions of consistently reported incidents to ASRS, such as altitude deviations, have been remarkably stable over many years. Therefore, users of ASRS may presume that incident reports drawn from a time interval of several or more years will reflect patterns that are broadly representative of the total universe of aviation safety incidents of that type."
17. NASA ASRS report no. 464683. February 2000.
18. NASA ASRS report no. 491679. November 2000.
19. NASA ASRS report no. 597122. October 2003.
20. U.K. Air Accidents Investigation Branch

(AAIB). AAIB bulletin no. 11/97, reference EW/A97/4/01.

21. U.K. Civil Aviation Authority (CAA). *Progress Report 1998: CAA and DETR Responses to Air Accidents Investigation Branch (AAIB) Safety Recommendations*. Civil Aviation Publication (CAP) 689.

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24. Garber, Ralph Michael; Van Kirk, Lawrence. "Conditional Maintenance Inspection." *Aero* Issue 14 (April 2001).

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29. NTSB accident report no. DCA97LA027.

30. Blake, Walter; Elliot, Richard. "The Last Two Minutes." *Boeing Airliner* (January–March 1991).

31. Carbaugh.

32. NTSB accident report no. LAX00LA192.

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34. FAA. FARs Part 121, *Operating Requirements: Domestic, Flag, and Supplemental Operations*. Part 121.438, "Pilot operating limitations and pairing requirements."

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39. FAA. Order 8400.9, *National Safety and Operational Criteria for Runway Use Programs*.

40. NASA ASRS report no. 524020. September 2001.

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43. FSF ALAR Task Force; FSF Editorial Staff. "ALAR Briefing Notes." *Flight Safety Digest* Volume 19 (August–November 2000).

44. Bland, Jeff; Carbaugh, David. "Preventing Hard Nosegear Touchdowns." *Aero* Issue 18 (April 2002).

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46. Boeing Flight Operations Safety. *A Matter of Seconds: Airplane Derotation*. 2001.

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Appendix
Turbojet Airplane Hard-landing Accidents and Incidents, 1996–2002

Date	Location	Airplane Type	Airplane Damage	Injuries
March 8, 1996	Halifax, Nova Scotia, Canada	Boeing 767-300	substantial	100 none
Weather conditions were near the published minimums for the localizer back-course approach to Runway 06. The flight crew conducted the approach during nighttime, with freezing drizzle and winds from 090 degrees at five knots to 10 knots. The airplane was slightly right of the extended runway centerline when the crew saw the runway environment at the minimum descent altitude. The report said that the upsloping runway created a visual illusion that caused both pilots to perceive that the airplane was higher than it was and to make an unwarranted reduction of thrust about 10 seconds before touchdown. The airplane touched down hard 200 feet (61 meters) past the runway threshold; pitch attitude was higher than normal, and the airplane's tail struck the runway. The report said that the flight crew did not use the runway's precision approach path indicator (PAPI) lights for vertical guidance during the approach.				
May 16, 1996	Anchorage, Alaska, U.S.	McDonnell Douglas MD-11	substantial	1 minor, 1 none
The flight crew conducted a visual approach to Runway 24R in daytime visual meteorological conditions (VMC) with winds from 170 degrees at nine knots. The crew of a Boeing 747 was conducting a parallel approach to Runway 24L ahead of the MD-11. The runways were 550 feet (168 meters) apart; the threshold of Runway 24L was 4,300 feet (1,312 meters) beyond the threshold of Runway 24R. The report said that the staggered runway thresholds positioned the normal approach path to Runway 24R lower than that of Runway 24L. The MD-11 encountered wake turbulence from the B-747 about 50 feet above the runway and entered a high sink rate. The captain increased power and nose-up pitch attitude to begin a go-around, but the airplane continued to descend. The captain discontinued the go-around when the airplane touched down on the lower-aft fuselage and bounced. The airplane bounced two more times before the landing was completed. The airplane's aft pressure bulkhead was substantially damaged. The captain received minor injuries. The report said that the probable cause of the accident was "improper in-flight planning/decision [making], which allowed the [MD-11] to encounter wake turbulence from [the B-747]."				
May 25, 1996	Los Angeles, California, U.S.	McDonnell Douglas MD-11	substantial	2 none
The first officer hand-flew a visual approach to Runway 25L in daytime VMC with winds from 250 degrees at 15 knots. Recorded flight data indicated that the airplane was 50 feet above ground level (AGL) when airspeed decreased 10 knots below V_{REF} (landing reference speed) and the rate of descent increased. The airplane's pitch attitude was 12 degrees nose-up when the main landing gear and the tail touched down on the runway. The report said that the probable cause of the accident was the flight crew's failure to maintain the proper approach airspeed and rate of descent.				
June 28, 1996	Aldan, Russia	Yakovlev Yak-40	destroyed	11 minor/none
About 23 minutes after departing from Tynda, the flight crew had problems with the no. 2 engine and shut down the engine (the airplane had three engines). The crew continued the flight to Aldan. During the landing in daytime VMC, the airplane touched down hard on the nose gear about 90 meters (295 feet) before the runway threshold and bounced several times. The nose-gear assembly separated from the airplane.				
Aug. 25, 1996	Jamaica, New York, U.S.	Lockheed L-1011-100	substantial	262 none
The flight crew began conducting the Category II instrument landing system (ILS) approach to Runway 04R with the airplane's autoland system engaged in daytime instrument meteorological conditions (IMC). The airplane was about seven nautical miles (13 kilometers) from Runway 04R, inbound to the final approach fix, when visibility decreased below published minimums for the approach. The approach controller told the crew that visibility was above the published minimums for the Category I ILS approach to Runway 04L and provided the ILS frequency and final approach course. The report said that while the crew transitioned for the Category I ILS approach to Runway 04L, the first officer (the pilot flying) was unable to engage the autothrottles. The captain told the first officer to manually operate the throttle levers. The airplane was flown through 500 feet AGL at 151 knots with engine thrust near idle. The airplane operator's requirements for a stabilized approach included the following statement: "The aircraft must not continue descent below 500 feet on any approach unless it is in the landing configuration, stabilized on final approach airspeed and sink rate with the engines spun up. Any time these conditions are not met when the aircraft is at or below 500 feet, a go-around is mandatory." When the airplane was flared for landing by the autoland system, the first officer retarded the throttles. The stick-shaker (stall-warning) system activated, and the captain advanced the throttle levers. The airplane touched down hard, and the tail struck the runway. The captain took control of the airplane and completed the landing. The report said that the probable causes of the accident were the "failure of the flight crew to complete the published checklist and to adequately cross-check the actions of each other, which resulted in their failure to detect that the leading-edge slats had not extended."				
Feb. 6, 1997	St. John's, Antigua	Airbus A300-600R	substantial	170 none
During a very-high-frequency omnidirectional radio (VOR) approach to Runway 07 in daytime VMC, the flight crew maneuvered the airplane to avoid traffic about 2,500 feet AGL. The flight crew said that the airplane was "slightly high" at 1,000 feet AGL. The report said that digital flight data recorder (DFDR) data indicated that at 500 feet AGL, airspeed was 143 knots — 15 knots higher than the "reference speed" — and that the engines were producing minimum thrust. Pitch attitude then increased from 0.5 degree nose-down to nine degrees nose-up, descent rate decreased from 1,700 feet per minute to 1,000 feet per minute, and glide path angle decreased from 5.8 degrees to 2.7 degrees. The airplane touched down on the main landing gear and bounced. Nose-up pitch attitude increased to 11 degrees, and the airplane's tail struck the runway. The report said that the probable cause of the accident was the captain's failure "to establish and maintain a stabilized approach (or perform a go-around)" and his excessive pitch application during recovery from the bounced landing. After the accident, the airplane operator told investigators that it had adopted a recommendation by Flight Safety Foundation that "companies should declare and support no-fault go-around and missed-approach policies."				

Appendix

Turbojet Airplane Hard-landing Accidents and Incidents, 1996–2002 *(continued)*

Date	Location	Airplane Type	Airplane Damage	Injuries
Feb. 14, 1997	Carajas, Brazil	Boeing 737-200	destroyed	1 fatal, 4 serious, 52 minor/none
After a VOR approach to Runway 10 in daytime IMC with winds from 140 degrees at 10 knots, the airplane touched down hard, and the right-main landing gear collapsed. The airplane overran the runway, crossed a ditch and came to a stop in a wooded area.				
Feb. 28, 1997	Kuala Lumpur, Malaysia	Canadair Challenger 601	minor	9 minor/none
The flight crew conducted an ILS approach to Runway 33 in daytime IMC with local thunderstorm activity and heavy rain. The surface winds were reported from 250 degrees at 15 knots, but the airplane's equipment indicated that the winds were from 210 degrees at 19 knots. During the landing flare, the airplane began to balloon (rise slightly in ground effect), and the pilot not flying apparently deployed the flight spoilers. The stall-warning system (stick shaker) activated, and the airplane touched down hard on the right-main landing gear and the nose landing gear, and bounced. The airplane then touched down on the left-main landing gear. The crew completed the landing without further incident and taxied the airplane to the parking area. The report said that the airplane flight manual prohibited use of flight spoilers below 300 feet.				
March 22, 1997	Manaus, Brazil	Boeing 747-200B	minor	7 none
The first officer, the pilot flying, said that his vision was affected by glare from the rising sun during a landing in VMC but that he believed the airplane was in the correct landing attitude. The captain perceived that no flare was being performed, took control of the airplane and began a flare two seconds before touchdown. The report said that this action resulted in an increased sink rate. Descent rate was 1,100 feet per minute (18 feet per second) when the airplane touched down. A postflight inspection revealed wrinkles in the fuselage skin.				
April 5, 1997	Lilongwe, Malawi	Boeing 747-400	substantial	3 minor, 147 none
The first officer was the pilot flying during an ILS approach to Runway 14 in daytime VMC with surface winds from 100 degrees at seven knots. The captain took control of the airplane at 1,000 feet for a visual approach. The airplane entered rain showers at about 500 feet; the captain said that he had sufficient visual cues to continue the landing. The first officer recommended that he activate his windshield wipers, but the captain declined because he previously had found the movement and noise of the windshield wipers to be distracting. The report said that the captain did not flare the airplane for landing. The ground-proximity warning system (GPWS) generated a "sink rate" warning just before the airplane, which was near its maximum landing weight, touched down hard with a descent rate of 1,070 feet per minute (18 feet per second) and bounced. The first officer observed that the airplane was airborne off the right side of the runway; he called for a go-around and applied full power. The flight crew landed the airplane without further incident on Runway 32. A postflight inspection by the first officer and the station maintenance manager revealed no external damage. The airplane then was flown to London, England, where an inspection revealed damage to the fuselage skin aft of the wings. Subsequent inspections revealed damage to the fuselage keel-beam web and to some of the wheel hubs.				
May 8, 1997	Shenzhen, China	Boeing 737-300	destroyed	35 fatal, 35 serious/minor, 4 none
During a nighttime approach in IMC with local thunderstorm activity and heavy rain, the airplane touched down hard and bounced. The flight crew conducted a go-around and declared an emergency during initial climb. The crew attempted a landing on the runway in the opposite direction; the airplane broke up when it struck the runway and began to burn.				
May 22, 1997	Newark, New Jersey, U.S.	Boeing 767-300ER	substantial	168 none
The first officer, who had 68 flight hours in type, hand-flew an ILS approach to Runway 04R in daytime VMC with surface winds from 320 degrees at 16 knots, gusting to 25 knots. The airplane was descending through 30 feet AGL about five seconds before touchdown when an onboard wind shear alert was generated. The report said that the flare was begun one second to two seconds before touchdown. After the airplane touched down on the main landing gear, the first officer applied nose-down pitch control, and the nose landing gear struck the runway. The report said that probable causes of the accident were the first officer's improper landing flare and the captain's inadequate supervision of the flight.				
July 31, 1997	Newark, New Jersey, U.S.	McDonnell Douglas MD-11	destroyed	5 minor
The flight crew conducted an ILS approach to Runway 22R in nighttime VMC with surface winds from 260 degrees at seven knots. The airplane touched down hard on the main landing gear, bounced and began to roll right. The airplane then touched down hard on the right-main landing gear. The right-main landing gear and the right wing outboard of the engine nacelle separated, and the airplane came to a stop inverted and burned. The report said that the probable causes of the accident were "the captain's overcontrol of the airplane during the landing and his failure to execute a go-around from a destabilized flare."				
Oct. 24, 1997	Montevideo, Uruguay	McDonnell Douglas MD-11F	minor	3 none
The report said that the airplane touched down hard, and the tail struck the runway.				
Dec. 24, 1997	Amsterdam, Netherlands	Boeing 757	substantial	3 minor, 210 none
Surface winds were reported from 230 degrees at 33 knots, gusting to 45 knots, when the flight crew landed the airplane on Runway 19R in nighttime VMC. The fuselage was not aligned with the runway when the airplane touched down hard, and the nose landing gear collapsed. The airplane slid about 3,000 meters (9,843 feet) and came to a stop off the side of the runway.				

Appendix
Turbojet Airplane Hard-landing Accidents and Incidents, 1996–2002 *(continued)*

Date	Location	Airplane Type	Airplane Damage	Injuries
Feb. 27, 1998	Jakarta, Indonesia	Boeing 737-500	substantial	93 minor/none
The first officer was the pilot flying when the flight crew began an ILS approach to Runway 25 in VMC. During final approach, the airplane was flown into a squall with heavy rain. Sink rate increased, and the airplane touched down hard, bounced and touched down again in a nose-high attitude, which resulted in a tail strike. The crew completed the landing and stopped the airplane on the runway.				
July 18, 1998	Seattle, Washington, U.S.	Douglas DC-8-63F	substantial	5 none
The flight crew conducted an ILS approach in weather conditions that included a 200-foot ceiling and one statute mile (two kilometers) visibility. The first officer was the pilot flying. Air traffic control (ATC) radar showed that the airplane's flight path deviated from the localizer course and the glideslope. When the airplane descended below the clouds, it was left of the runway centerline. The captain told the first officer, "Push it down. You got it? Or [do] you want me to get it?" The first officer said, "I can get it." The first officer applied nose-down pitch control and banked the airplane about 14 degrees right to align it with the runway centerline. A high sink rate developed, and the airplane touched down hard. A wheel on the main landing gear separated, entered the ramp area and struck two trucks and a baggage cart in front of the main terminal building. An examination of the wheel-retaining nut showed that it was worn beyond engineering-drawing specifications. The report said that the probable cause of the accident was the flight crew's "failure to perform a missed approach upon failing to attain and/or maintain proper course/runway alignment and glide path on final approach."				
July 19, 1998	Kos, Greece	Lockheed L-1011	substantial	370 none
During a VOR/DME approach to Runway 33 at 0400 local time in VMC with winds from 010 degrees at 16 knots, a sudden wind shift caused a high sink rate to develop when the airplane was close to the runway. The commander increased nose-up pitch attitude, and the airplane landed hard, striking its tail on the runway. The report said that the flight crew likely was experiencing a reduced level of alertness when the accident occurred. The crew had been on standby when they were called to conduct the flight, which departed from London, England, at 2230 local time (0030 Kos time). Their standby duty had been scheduled to end at 2000. Except for a 40-minute nap by the commander before reporting for duty, the commander and the first officer had been awake more than 20 hours when the accident occurred.				
Aug. 14, 1998	Juneau, Alaska, U.S.	Boeing 737-400	substantial	145 none
The first officer, who was making his second initial operating experience (IOE) training flight, was the pilot flying when the airplane bounced on touchdown during a visual approach to Runway 26 in daytime VMC. The captain/check airman observed that the throttle levers were not fully retarded; he moved the throttle levers to flight idle and told the first officer to maintain the airplane's pitch attitude. The autospoilers then deployed, and the airplane touched down in a nose-high attitude. The captain said that the second touchdown was firm but within acceptable limits. A postflight inspection revealed a 1.0-foot by 4.0-foot (0.3-meter by 1.2-meter) scrape on the bottom of the rear fuselage. The report said that the accident was caused by the flight crew's inadequate recovery from the bounced landing.				
Dec. 28, 1998	Curitiba, Brazil	Embraer EMB-145RJ	destroyed	40 minor/none
The airplane descended below clouds about 300 feet AGL during a hand-flown ILS approach to Runway 15 in daytime IMC with winds from 080 degrees to 090 degrees at four knots. The flight crew observed that the airplane was high on the approach and reduced power to flight idle. Rate of descent increased to 1,800 feet per minute (30 feet per second), and the crew increased power about two seconds before touchdown. The airplane touched down hard; the fuselage failed near the wing trailing edge, and the tail of the airplane drooped and struck the runway.				
Jan. 15, 1999	London, England	Boeing 767-300ER	minor	191 none
The flight crew briefed for a nighttime approach and landing on Runway 27L at London Heathrow Airport. During descent, the landing runway was changed to Runway 27R. The crew rebriefed for the approach and landing. Surface winds were from 220 degrees at 11 knots. After the crew acquired visual contact with the runway at 3,000 feet, the commander disengaged the autopilot and hand-flew the approach. The airplane encountered light chop, but the approach was stabilized. The commander began the flare about 30 feet AGL, then reduced power to idle as the airplane neared the runway. He said that the main landing gear touched down gently, but the airplane then began "skipping slightly" and "porpoising," and the nosewheel touched down hard. The crew completed the landing and taxied the airplane to the gate. Examination revealed compression buckling and a tear in the fuselage skin, and damage to some stringers. The report said that the damage was the result of a pilot-induced oscillation that likely was initiated by excessive forward control column movement after touchdown. The report said that the accident might have been prevented if the autospoilers had been armed before landing.				
Jan. 28, 1999	Catania, Italy	McDonnell Douglas MD-82	substantial	84 minor/none
The airplane was descending through about 100 feet during a nighttime approach to Fontanarossa Airport when it encountered wind shear. The pilot flying applied full power and began a go-around, but the airplane continued to descend and touched down hard on the runway. The left-main landing gear separated, and the left wing struck the ground.				

Appendix

Turbojet Airplane Hard-landing Accidents and Incidents, 1996–2002 *(continued)*

<table>
<tr><th>Date</th><th>Location</th><th>Airplane Type</th><th>Airplane Damage</th><th>Injuries</th></tr>
<tr><td>June 2, 1999</td><td>Phoenix, Arizona, U.S.</td><td>Boeing 757-200</td><td>substantial</td><td>127 none</td></tr>
<tr><td colspan="5">During a visual approach in nighttime VMC, the airplane bounced on touchdown, and the captain applied nose-down pitch control. Recorded data showed that the pitch attitude changed rapidly (four degrees per second) from 5.8 degrees nose-up to 0.7 degree nose-down. The captain said that he "felt a jolt" when the nose landing gear touched down on the runway. Postflight examination revealed damage to the aft bulkhead and associated structure in the nose-gear wheel well and nearby skin panels. The report said that the probable cause of the accident was "the pilot's excessive and rapid forward control-column movement in response to a bounced landing."</td></tr>
<tr><td>June 9, 1999</td><td>Zhanjiang, China</td><td>Boeing 737-300</td><td>destroyed</td><td>4 minor, 71 none</td></tr>
<tr><td colspan="5">The airplane touched down hard and bounced during a landing at Guangdong Airport during daytime IMC with strong winds and rain. The report said that the flight crew apparently lost control of the airplane after it touched down again. The airplane overran the runway, and the landing gear collapsed.</td></tr>
<tr><td>July 15, 1999</td><td>Jamaica, New York, U.S.</td><td>Airbus A300-600ER</td><td>substantial</td><td>190 none</td></tr>
<tr><td colspan="5">The first officer (the pilot flying) was receiving IOE training as a captain. After an apparently normal approach to Runway 13L at John F. Kennedy International Airport in daytime VMC with surface winds from 190 degrees at 15 knots, the first officer aligned the fuselage with the runway centerline about 30 feet AGL and abruptly reduced power to idle about 10 feet AGL. The sink rate increased, and the airplane touched down hard on the right-main landing gear, bounced and touched down again four seconds later. The airplane's tail struck the runway during the second touchdown. The report said that just before each touchdown, the first officer pulled back on the control column. The report said that the probable causes of the accident were "improper use of the flight controls by the captain-trainee and inadequate supervision by the check airman."</td></tr>
<tr><td>Aug. 22, 1999</td><td>Hong Kong, China</td><td>McDonnell Douglas MD-11</td><td>destroyed</td><td>4 fatal, 50 serious, 261 minor/none</td></tr>
<tr><td colspan="5">The flight crew conducted an ILS approach to Runway 25L at Chep Lap Kok International Airport in daytime IMC with heavy rain and strong gusting winds associated with a tropical storm. The airplane touched down hard (between 18 feet per second and 20 feet per second) on the right-main landing gear, and the right wing separated. The airplane rolled inverted and came to a stop beside the runway. Postimpact fires were extinguished by airport rescue and fire fighting personnel.</td></tr>
<tr><td>Aug. 27, 1999</td><td>Glennallen, Alaska, U.S.</td><td>Learjet 35</td><td>substantial</td><td>4 none</td></tr>
<tr><td colspan="5">The first officer was the pilot flying during a daytime VOR approach to Runway 14. After descending below the clouds about 2,400 feet AGL, the flight crew observed that the airplane was high and left of the runway centerline. The first officer conducted a right turn, reduced power and applied nose-down pitch control. As the airplane passed over the runway threshold, the crew observed a rapid decrease in airspeed and an excessive descent rate. The captain took control of the airplane and increased engine power to maximum to "cushion the touchdown." The captain told investigators that the touchdown was firm but within acceptable limits and that the initial touchdown was on the left-main landing gear. The crew did not conduct a postflight inspection of the airplane. Before takeoff about 45 minutes later, the first officer conducted a "quick walk-around inspection" of the airplane and observed no anomalies. The crew then conducted an emergency medical services flight to Anchorage, Alaska, where ground personnel found a 3.3-foot (1.0-meter) scrape on the bottom of the left wing-tip fuel tank and wrinkled skin on an upper wing panel.</td></tr>
<tr><td>Sept. 9, 1999</td><td>Nashville, Kentucky, U.S.</td><td>Douglas DC-9-31</td><td>substantial</td><td>3 minor, 43 none</td></tr>
<tr><td colspan="5">The first officer was the pilot flying during a visual approach to Runway 02L in daytime VMC. The surface winds were from 360 degrees at nine knots, gusting to 16 knots. The report said that the first officer did not maintain the proper descent rate, and the airplane touched down hard on the right-main landing gear and bounced. The captain then took control of the airplane and completed the landing. During the landing roll, the left-main landing gear collapsed. The captain told investigators that he believed that the first officer was not going to make a good landing. The captain did not take corrective action before the initial touchdown, other than to tell the first officer to increase power. Examination of the left-main landing-gear assembly revealed a pre-existing crack in the outer cylinder housing. The report said that the probable causes of the accident were the pre-existing crack and "the first officer's failure to maintain the proper rate of descent, resulting in a hard landing on touchdown."</td></tr>
<tr><td>Oct. 26, 1999</td><td>Yangon, Myanmar</td><td>Airbus A320-200</td><td>substantial</td><td>92 minor/none</td></tr>
<tr><td colspan="5">During a landing on Runway 02 at Mingaladon Airport in nighttime IMC with heavy rain, the airplane touched down hard, bounced and touched down again on the nose landing gear, which separated from the airplane. The airplane traveled about 4,000 feet (1,220 meters) down the runway before overrunning the runway onto soft ground. Before the airplane came to a stop, the main landing gear partially collapsed, and the no. 1 engine struck the ground.</td></tr>
</table>

Appendix

Turbojet Airplane Hard-landing Accidents and Incidents, 1996–2002 *(continued)*

<table>
<tr><th>Date</th><th>Location</th><th>Airplane Type</th><th>Airplane Damage</th><th>Injuries</th></tr>
<tr><td>Nov. 18, 1999</td><td>Rio de Janeiro, Brazil</td><td>Fokker 100</td><td>substantial</td><td>107 minor/none</td></tr>
<tr><td colspan="5">The airplane's left-main landing gear collapsed during a hard landing at Santos Dumont Airport in daytime VMC. The airplane came to a stop off the left side of the runway.</td></tr>
<tr><td>Dec. 27, 1999</td><td>Shannon, Ireland</td><td>Airbus A310-300</td><td>substantial</td><td>189 minor/none</td></tr>
<tr><td colspan="5">The airplane encountered thunderstorm-related turbulence during an ILS approach to Runway 06 in twilight VMC with surface winds reported from 260 degrees at two knots. The report said that the approach was not stabilized and the landing flare was begun late. The airplane bounced on touchdown, and the pilot flying increased power and pushed the control column forward, reducing nose-up pitch by nine degrees. The airplane touched down hard on the nosewheel, which bounced off the runway. A nose-down pitch-control input of 14 degrees was made, and the nosewheel again touched down hard. The flight crew completed the landing without further incident and taxied the airplane to the gate. While taxiing, the crew told ATC that they had encountered wind shear and a variable head wind of 47 knots.</td></tr>
<tr><td>Feb. 12, 2000</td><td>Luanda, Angola</td><td>Boeing 727-100</td><td>destroyed</td><td>7 none</td></tr>
<tr><td colspan="5">Heavy rain and surface wind gusts between 50 knots and 80 knots were reported at the airport. During the first ILS approach to Runway 23, the flight crew conducted a missed approach because the airplane was not aligned with the runway. Witnesses said that after the second approach, the airplane's right wing struck the runway during the landing flare. The airplane then touched down hard, and the fuselage separated behind the wing root.</td></tr>
<tr><td>Feb. 12, 2000</td><td>San Salvador, El Salvador</td><td>Boeing 757-200</td><td>substantial</td><td>161 none</td></tr>
<tr><td colspan="5">The report said that an improper flare resulted in a bounced landing. The flight crew said that the nose landing gear touched down more firmly than the main landing gear and that a postflight inspection of the airplane revealed no abnormalities. The crew flew the airplane to Atlanta, Georgia, U.S.; another flight crew then flew the airplane to Los Angeles, California, U.S. After landing the airplane in Los Angeles, the crew observed that the fuselage was buckled near the nose-gear door. Further examination revealed that structures inside the wheel well were bent and fractured.</td></tr>
<tr><td>April 14, 2000</td><td>Guayaquil, Ecuador</td><td>Lockheed L-1011</td><td>substantial</td><td>4 none</td></tr>
<tr><td colspan="5">The airplane was substantially damaged during a hard landing on Runway 21 at Simon Bolivar International Airport in nighttime VMC.</td></tr>
<tr><td>May 9, 2000</td><td>Maui, Hawaii, U.S.</td><td>Lockheed L-1011</td><td>substantial</td><td>370 none</td></tr>
<tr><td colspan="5">The flight crew conducted an ILS approach to Runway 02 in daytime VMC with winds reported from 060 degrees at 22 knots, gusting to 27 knots. About 40 feet AGL, a high sink rate suddenly developed and the captain increased power and nose-up pitch. All three flight crewmembers said that the touchdown was harder than normal but not one that they would classify as a hard landing. Several flight attendants said that the airplane "slammed down" onto the runway and that two ceiling panels were dislodged. Eight flight attendants received medical evaluation of reported neck pain and back pain, and subsequently were released from a medical facility near the airport. During a postflight inspection of the airplane, the flight engineer found damage to the lower rear fuselage. A maintenance inspection revealed damage, consistent with a tail strike, to the pressure bulkhead and to several bell frames and stringers in the aft fuselage. The report said that at the airplane's landing weight, V_{REF} was 138 knots and that, with head wind–correction factors, the target approach speed was 150 knots. During the 10 seconds before touchdown, airspeed decreased from 143 knots to 130 knots. The report said that the probable cause of the accident was "the captain's failure to maintain the proper wind-adjusted V_{REF} airspeed."</td></tr>
<tr><td>May 22, 2000</td><td>Taipei, Taiwan, China</td><td>Boeing MD-11</td><td>minor</td><td>2 none</td></tr>
<tr><td colspan="5">Nighttime VMC prevailed, but there were reports of wind shear at the airport. After an ILS approach to Runway 05L, a high sink rate developed during the landing flare, and the airplane touched down hard and bounced. The pilot flying apparently applied nose-down pitch control, and the airplane touched down hard on the nose landing gear. The crew conducted a go-around, and the airplane's tail struck the ground during rotation. The crew then landed the airplane without further incident.</td></tr>
<tr><td>May 24, 2000</td><td>Acapulco, Mexico</td><td>Learjet 23</td><td>substantial</td><td>5 none</td></tr>
<tr><td colspan="5">Soon before touchdown on Runway 28, the airplane encountered heavy rain and strong, gusting winds associated with local thunderstorm activity. The rate of descent increased rapidly, and the airplane touched down hard on the runway.</td></tr>
<tr><td>June 14, 2000</td><td>Lihue, Hawaii, U.S.</td><td>McDonnell Douglas DC-9-51</td><td>substantial</td><td>2 minor, 137 none</td></tr>
<tr><td colspan="5">The flight crew conducted a stabilized approach in daytime VMC, but the pilot flying (the first officer) misjudged and delayed the landing flare, the report said. DFDR data indicated that one second before touchdown, the airplane's rate of descent was higher than normal at 384 feet per minute (six feet per second), and the pitch attitude was eight degrees nose-up. During the hard landing and tail strike, several oxygen masks were dislodged from cabin-ceiling storage compartments. The captain observed no visible damage during a postflight inspection of the airplane. After flying the airplane back to Honolulu, Hawaii, the captain told maintenance personnel that a "firmer-than-routine" landing had been made at Lihue. A maintenance examination of the airplane revealed deformation of the aft empennage. The report said that the first officer had begun line flying five days before the accident and was not authorized to land at the Lihue airport.</td></tr>
</table>

Appendix
Turbojet Airplane Hard-landing Accidents and Incidents, 1996–2002 *(continued)*

Date	Location	Airplane Type	Airplane Damage	Injuries
July 18, 2000	Ahwaz, Iran	Fokker F28-4000	substantial	89 none
Visibility was reduced by blowing sand when the flight crew conducted a nighttime visual approach. Soon before touchdown, the pilot flying lost visual contact with the runway. The airplane touched down hard on the right side of the runway, bounced and touched down on hard ground off the right side of the runway. The crew then conducted a go-around and landed the airplane without further incident.				
Aug. 7, 2000	Ostend, Belgium	Boeing 707-320C	substantial	3 none
The cargo airplane was at 40 feet on final approach when the no. 2 engine surged and flamed out. After touching down hard, the airplane was taxied to the ramp. The no. 2 engine was replaced. Later, several fuel leaks developed during refueling; maintenance personnel found that the rear spar in the left wing was damaged.				
Sept. 19, 2000	Ho Chi Minh City, Vietnam	Boeing 767-300ER	substantial	212 none
Visibility was 1,500 meters (4,922 feet) in light rain when the airplane touched down hard on its nose landing gear. The landing was completed without further incident, and the airplane was taxied to the gate.				
Sept. 21, 2000	Niamey, Niger	Boeing 707-312B	destroyed	1 serious, 10 minor
The airplane was en route from Lomé, Togo, to Paris, France, at Flight Level 350 (approximately 35,000 feet) when the flight crew smelled a burning odor and observed smoke. The crew diverted to Niamey and conducted an emergency descent. The smoke intensified, and several electrical-system problems were encountered during the descent. The airplane touched down hard and bounced twice. The nose landing gear collapsed, and the airplane veered off the right side of the runway, where it was destroyed by fire.				
Sept. 23, 2000	Khartoum, Sudan	Boeing 737-300	minor	111 none
The second-in-command — a captain undergoing route validation — was the pilot flying when the airplane touched down hard. The accident occurred during daytime and in deteriorating weather conditions that included strong crosswinds.				
Nov. 24, 2000	Bangkok, Thailand	Boeing 737-400	substantial	155 minor/none
The airplane touched down hard, bounced and then touched down on the nose landing gear, which collapsed. The accident occurred during nighttime.				
Nov. 30, 2000	Shannon, Ireland	Boeing 737-800	substantial	9 minor, 186 none
Runway 24 was in use at the airport. Surface winds were from 140 degrees at 28 knots, gusting to 42 knots, and visibility was 10 kilometers (six statute miles) with light rain. Warnings were issued for severe turbulence and wind shear. The flight crews of two airplanes preceding the B-737 on the approach conducted go-arounds and diverted to Dublin, Ireland. The captain and the first officer (the pilot flying) of the B-737 said that the approach was stabilized until about 30 feet AGL, when the airplane's sink rate suddenly increased substantially. Both pilots believed that the airplane had encountered a downdraft. The first officer increased engine power and applied nose-up pitch control. The airplane touched down hard, bounced and touched down again on the nose landing gear, which collapsed. The airplane was stopped on the runway about 8,600 feet (2,623 meters) from the initial touchdown point. Airplane damage included engine foreign-object damage.				
Feb. 7, 2001	Bilbao, Spain	Airbus A320-200	substantial	142 minor/none
During an ILS approach to Runway 30 in nighttime VMC, the airplane encountered turbulence and wind shear. Surface winds were from 240 degrees at eight knots, gusting to 15 knots, and light turbulence had been reported. About 120 feet AGL, a strong updraft caused the airplane to deviate above the glideslope. As the pilot flying applied nose-down pitch control, a strong downdraft caused the airplane to enter a high sink rate. At 80 feet AGL, the flight crew began a go-around, but the airplane continued to descend and touched down hard — at an estimated descent rate of 1,200 feet per minute (20 feet per second) — in a nose-down attitude. The nose landing gear collapsed, and the airplane slid about 1,000 meters (3,281 feet) before coming to a stop on the runway. The report said, "The combination of a severe vertical gust together with the nose-up [side]stick input [during the go-around] resulted in the aircraft's AOA [angle-of-attack] protection being triggered. As a result of this accident, Airbus has decided to modify the AOA-protection control laws to give the crew more authority during the short-final-approach phase."				
Feb. 14, 2001	Punta Gorda, Florida, U.S	Learjet 35A	substantial	5 none
Reported visibility was 0.25 statute mile (0.40 kilometer) with fog. On arrival, the captain told ATC that he had the airport and the runway in sight. The airplane, which was on an emergency medical services flight, was at 800 feet during the nighttime VOR approach when the captain lost visual contact with the runway and conducted a go-around. The captain said that during the second approach, which was conducted visually, he was distracted by the fog but maintained visual contact with the runway. The first officer recommended a go-around, but the captain continued the approach. The tires on the left-main landing gear burst on touchdown, and the airplane traveled 4,100 feet (1,251 meters) down the runway before coming to a stop.				

Appendix
Turbojet Airplane Hard-landing Accidents and Incidents, 1996–2002 *(continued)*

<table>
<tr><th>Date</th><th>Location</th><th>Airplane Type</th><th>Airplane Damage</th><th>Injuries</th></tr>
<tr><td>March 8, 2001</td><td>St. Johns, Newfoundland, Canada</td><td>Boeing 757-200</td><td>minor</td><td>183 minor/none</td></tr>
<tr><td colspan="5">The airplane was being flown through 200 feet during an ILS approach to Runway 11 in daytime VMC when it encountered moderate-to-severe turbulence and strong crosswinds. Sink rate increased rapidly at about 20 feet, and the airplane landed hard. Surface winds were reported from 010 degrees at 20 knots, gusting to 27 knots. A flight crew who had landed a B-727 had reported moderate turbulence on final approach. After a visual inspection disclosed no apparent discrepancies, the B-757 flight crew conducted a positioning flight to Halifax, Nova Scotia. A maintenance examination disclosed no discrepancies, and the airplane was flown on a charter flight to Cuba. During departure, the left-main landing gear did not retract, and the crew diverted the flight to Florida, U.S., where damage consistent with a hard landing was found.</td></tr>
<tr><td>March 23, 2001</td><td>Monrovia, Liberia</td><td>Boeing 707-320C</td><td>destroyed</td><td>182 minor/none</td></tr>
<tr><td colspan="5">The flight crew conducted a nighttime ILS approach and encountered a shallow patch of fog just before touchdown. The pilot flying lost visual contact with the runway, and the airplane touched down hard and bounced. The airplane touched down again in a left-wing-low attitude, and the two left engines struck the runway and separated from the wing. The airplane came to a stop near the airport terminal building.</td></tr>
<tr><td>May 17, 2001</td><td>Bangkok, Thailand</td><td>Airbus A300-620R</td><td>minor</td><td>NA</td></tr>
<tr><td colspan="5">Surface winds were from 190 degrees at nine knots when the flight crew conducted an approach to Runway 21R in nighttime VMC. The first officer was the pilot flying. A higher-than-normal sink rate developed, and the airplane touched down hard and bounced. The captain took control of the airplane; during the recovery, a tail strike occurred. The landing was completed without further incident.</td></tr>
<tr><td>May 22, 2001</td><td>Yellowknife, Northwest Territories, Canada</td><td>Boeing 737-200C</td><td>substantial</td><td>104 none</td></tr>
<tr><td colspan="5">During a visual approach to Runway 33 in daytime VMC with winds from 140 degrees at two knots, the airplane entered a higher-than-normal sink rate during the flare, and the first officer (the pilot flying) increased engine power and applied nose-up pitch control. The throttle position prevented the ground spoilers from deploying on touchdown. "The combination of power application, high sink rate and the lack of spoiler deployment resulted in the aircraft rebounding," the report said. The captain took control of the airplane, reduced power and applied nose-down pitch control. The airplane touched down hard on the nose landing gear, and a nosewheel tire burst. The report said that the company's operating manual said that "in the event of a bounced landing, the pilot flying should hold or re-establish normal landing attitude; add thrust as necessary to control the sink rate; do not push over, as this may cause a second bounce and possibly damage to the nose gear."</td></tr>
<tr><td>Aug. 14, 2001</td><td>Kuujjuaq, Quebec, Canada</td><td>Dassault Falcon 10</td><td>substantial</td><td>10 minor/none</td></tr>
<tr><td colspan="5">The report said that the airplane was substantially damaged during a hard landing.</td></tr>
<tr><td>Sept. 16, 2001</td><td>Goiania, Brazil</td><td>Boeing 737-200</td><td>destroyed</td><td>67 minor/none</td></tr>
<tr><td colspan="5">The airplane touched down hard and bounced during a landing in daytime IMC with heavy rain. The airplane touched down again near the left side of the runway, veered off the runway, rolled about 600 meters (1,969 feet), rolled back onto the runway and ground-looped. The nose landing gear, right-main landing gear and right engine separated from the airplane during the accident.</td></tr>
<tr><td>Oct. 16, 2001</td><td>Roanoke, Virginia, U.S.</td><td>Embraer EMB-145LR</td><td>substantial</td><td>33 none</td></tr>
<tr><td colspan="5">The captain said that she briefed a "no-go-around" night visual approach because takeoffs were not authorized on the runway at night. The first officer said that she knew this was incorrect but did not challenge the captain. The approach was not stabilized, and airspeed decreased to stall speed. The first officer said that she initially made callouts of slow airspeed but stopped making the callouts when the captain failed to respond to them. The airplane was in a nose-high pitch attitude when the aft fuselage struck the runway. The airplane then settled onto the landing gear. During the investigation, the captain described the first officer as passive and quiet; the first officer described the captain as defensive and not amenable to criticism. Both pilots had received crew resource management (CRM) training. Investigators found that none of the company's manuals contained a definition of a stabilized approach. The report said that the probable cause of the accident was "the captain's failure to maintain airspeed, which resulted in an inadvertent stall/mush and hard landing."</td></tr>
<tr><td>Nov. 16, 2001</td><td>Cairo, Egypt</td><td>Airbus A321-200</td><td>substantial</td><td>88 minor/none</td></tr>
<tr><td colspan="5">Surface winds were from 340 degrees at 12 knots when the flight crew conducted a daytime ILS approach to Runway 05. As the airplane was flown through 200 feet, it ballooned, and the pilot flying applied nose-down pitch control to regain the glideslope. The airplane then began to settle as it was flown through about 100 feet, and the pilot applied nose-up pitch control. The tail of the airplane struck the runway during touchdown. The landing was completed without further incident.</td></tr>
</table>

Appendix
Turbojet Airplane Hard-landing Accidents and Incidents, 1996–2002 *(continued)*

Date	Location	Airplane Type	Airplane Damage	Injuries
Nov. 20, 2001	Taipei, Taiwan, China	Boeing MD-11P	substantial	220 none
After an ILS approach to Runway 06 in daytime VMC, a high rate of descent developed about 50 feet AGL. The first officer was the pilot flying. The airplane touched down hard, and the captain took control and conducted a go-around. The airplane was landed without further incident. Examination of the airplane disclosed that the left tire on the nosewheel had failed and that the nosewheel area was damaged.				
Dec. 9, 2001	Lawrence, Kansas, U.S.	Dassault Falcon 100	substantial	2 none
During a visual approach in daytime VMC, the airplane pitched nose-down about 20 feet AGL. Both pilots said that they applied nose-up pitch control but were not able to adjust the pitch attitude for a normal landing. The airplane landed hard, breaking the left-main landing-gear strut, which penetrated the upper wing skin. After the accident, the pilots observed that the horizontal-stabilizer-trim indicator indicated full-nose-down trim and that the horizontal stabilizer appeared to be trimmed full-nose-down. The report said that a preliminary examination of the airplane showed that the horizontal stabilizer was positioned four degrees nose-down. The report said that the probable cause of the accident was "the copilot's failure to maintain aircraft control during the landing" and that contributing factors were "the copilot's improper in-flight decision not to execute a go-around, … inadequate crew coordination prior to landing … and the improperly set stabilizer trim."				
Jan. 6, 2002	Canary Islands, Spain	Boeing 737-400	substantial	86 minor/none
The airplane touched down hard while landing at Puerta del Rosario International Airport in daytime IMC. Strong winds were reported at the airport.				
Feb. 1, 2002	London, England	Airbus A300B4	minor	3 none
A captain-in-training was the pilot flying during a nighttime positioning flight with no cargo aboard the airplane. The flight crew conducted an ILS approach to Runway 26L at London Gatwick Airport. Surface winds were reported from 210 degrees at 18 knots, gusting to 30 knots. At about 1,000 feet, the commander observed an inertial reference system (IRS) wind-speed readout of 70 knots. When the pilot flying began the flare, the left wing lowered; he applied right-aileron control and increased power. The airplane touched down first on the left-main landing gear, then on the right-main landing gear, and bounced. The pilot flying applied nose-down pitch control, and the airplane touched down hard on the nose landing gear and the right-main landing gear, causing the right-engine nacelle to strike the runway.				
Feb. 14, 2002	West Palm Beach, Florida, U.S.	Gulfstream V	substantial	2 none
Soon after departure, the flight crew requested clearance to return to the airport because the landing gear had not retracted on command. As the airplane was flared for landing, the ground spoilers deployed. The airplane landed hard, and the right-main landing gear collapsed. The report said that wooden sticks were found in the weight-on-wheels switches for both main landing gear. The airplane was on jacks for a tire change when a maintenance technician used the sticks to disable the weight-on-wheels system so that he could access the maintenance-data-acquisition unit to check an overspeed message. The sticks were not removed after maintenance was completed. As a result, the airplane remained in ground mode, and the ground spoilers deployed when the crew moved the throttle levers to idle during the flare.				
Feb. 18, 2002	Mashad, Iran	Tupolev Tu-154M	substantial	NA
The airplane was damaged during a hard landing. The report said that further damage occurred when the nose landing gear collapsed while the airplane was being moved during maintenance in Moscow, Russia.				
March 18, 2002	Belo Horizonte, Brazil	Boeing 737-100QC	substantial	3 none
The airplane touched down hard after a visual approach during nighttime VMC. The left-main landing gear began to collapse during the landing roll. The airplane overran the runway, traveled about 200 meters (656 feet) and ground-looped before coming to a stop. The left-main landing gear, nose landing gear, forward-fuselage belly, left engine and left wing were damaged.				
April 2, 2002	Cairo, Egypt	Airbus A320-230	substantial	NA
The report said that the airplane was damaged in a hard landing.				
April 21, 2002	Wamena, Irian Jaya, Indonesia	Antonov An-72	destroyed	5 minor/none
After a visual approach in daytime VMC, the airplane bounced on touchdown and then touched down hard on the nose landing gear, which collapsed. After the airplane came to a stop on the runway, a fire that began in the nose landing gear area spread and destroyed much of the fuselage before being extinguished by aircraft rescue and fire fighting personnel.				

Appendix
Turbojet Airplane Hard-landing Accidents and Incidents, 1996–2002 *(continued)*

<table>
<tr><th>Date</th><th>Location</th><th>Airplane Type</th><th>Airplane Damage</th><th>Injuries</th></tr>
<tr><td>April 25, 2002</td><td>Lake in the Hills, Illinois, U.S.</td><td>Cessna Citation 560</td><td>substantial</td><td>2 none</td></tr>
<tr><td colspan="5">The first officer, who had 23 flight hours in type, was the pilot flying during a positioning flight in daytime VMC. The captain said that the approach to the 3,058-foot (933-meter) runway was normal and “on speed,” and that the flare was begun at the proper height; the first officer then applied nose-down pitch control, and the airplane landed “firmly” on all three landing gear and bounced. The captain said that the first bounce was not severe enough to warrant a go-around, but successive bounces were worse. After the second bounce or third bounce, the captain took control of the airplane. He said that the last bounce was high, but airspeed was too slow to conduct a go-around. The last touchdown damaged the nose landing gear. The crew shut down the airplane on the runway. The report said that the probable cause of the accident was “the flight crew’s delay in executing a go-around.”</td></tr>
<tr><td>May 22, 2002</td><td>Gibraltar, U.K.</td><td>Boeing 757-200</td><td>substantial</td><td>175 none</td></tr>
<tr><td colspan="5">The crew conducted a visual approach to Runway 27 in daytime VMC with surface winds from 260 degrees at 23 knots. The report said that the flare and touchdown were normal but that after the main landing gear touched down, the captain applied full nose-down pitch control. The airplane rapidly pitched nose-down, and the nosewheel touched down hard on the runway. The landing was completed without further incident. After the airplane was taxied to the gate, significant damage to the forward fuselage in the area of the nosewheel was found.</td></tr>
<tr><td>June 16, 2002</td><td>Kansas City, Missouri, U.S.</td><td>McDonnell Douglas DC-9-82</td><td>substantial</td><td>123 none</td></tr>
<tr><td colspan="5">The first officer, who was receiving IOE training as a captain, hand-flew a night visual approach with the autothrottles engaged. The airplane was descending through 100 feet AGL when the check airman observed that airspeed was slightly below V_{REF} and told the first officer not to allow the airspeed to slow further. At 40 feet AGL, the check airman observed that the throttles were at idle and that the autothrottles were engaged. “He determined that the only action to take was to ensure that the nose of the airplane was not raised [in an effort] to cushion the landing,” the report said. The jump seat occupant said that the flare appeared to begin when the airplane was “a little high” and that pitch attitude then was reduced; a high sink rate developed, and an additional pitch change was made, resulting in a “firm” landing. A postflight maintenance inspection revealed damage to the tail skid and adjacent structure.</td></tr>
<tr><td>Aug. 9, 2002</td><td>Lisbon, Portugal</td><td>Airbus A320-210</td><td>minor</td><td>126 minor/none</td></tr>
<tr><td colspan="5">The flight crew conducted an ILS approach to Runway 03 in daytime VMC with surface winds from 360 degrees at 14 knots. The first officer was the pilot flying. The airplane touched down hard on the left-main landing gear, then on the right-main landing gear, and bounced. The captain took control of the airplane. The second touchdown also was hard, but the landing was completed without further incident.</td></tr>
<tr><td>Aug. 18, 2002</td><td>Olbia, Sardinia, Italy</td><td>Learjet 35A</td><td>substantial</td><td>2 minor/none</td></tr>
<tr><td colspan="5">The report said that the airplane was substantially damaged in a hard landing.</td></tr>
<tr><td>Aug. 22, 2002</td><td>London, England</td><td>British Aerospace BAe 125-800</td><td>minor</td><td>3 none</td></tr>
<tr><td colspan="5">The first officer, who had 219 flight hours in type, was the pilot flying during the approach to RAF Northolt in daytime VMC. The flight crew accepted an ATC request to conduct a precision approach radar (PAR) approach to facilitate controller training and were given radar vectors to land on Runway 25. Winds were variable at three knots. The report said, “The crew calculated the threshold speed to be 117 knots, and the commander provided instructional assistance to the first officer, who was unfamiliar with the PAR procedure.” The report said that the correct threshold speed for the airplane’s landing weight was 124 knots. Radio transmissions indicated that the crew maintained the 3.5-degree glide path until the airplane was 1.5 nautical miles (2.8 kilometers) from touchdown. The airplane drifted slightly below the glide path and then drifted “well above” the glide path. The airplane was about seven feet AGL during the flare when the stick-shaker activated and the left wing dropped rapidly. Recorded DFDR data indicated that airspeed was 101 knots just before touchdown. The airplane touched down hard on the left-main landing gear. A postflight inspection revealed damage to the left wing tip fairing and flap.</td></tr>
</table>

AGL = Above ground level ATC = Air traffic control CRM = Crew resource management DFDR = Digital flight data recorder
GPWS = Ground-proximity warning system ILS = Instrument landing system IOE = Initial operating experience
IMC = Instrument meteorological conditions NA = Information not available VMC = Visual meteorological conditions
VOR = Very-high-frequency omnidirectional radio V_{REF} = Landing reference speed

Sources: Airclaims; Aviation Accident Investigation Commission of Brazil; Transportation Safety Board of Canada; Dutch Transport Safety Board; Indian Ministry of Civil Aviation; Irish Air Accident Investigation Unit; Aviation Safety Council of Taiwan, China; U.K. Air Accidents Investigation Branch; U.S. National Transportation Safety Board.

Number of Canadian Aircraft Involved in Accidents in 2003 Declines from Five-year Average

The number of Canadian airplanes involved in accidents was higher in 2003 than in 2002, and the number of helicopters involved in accidents was lower.

—FSF EDITORIAL STAFF

The number of accidents involving Canadian-registered airplanes in 2003 was higher than the number for 2002, but was lower than the annual average for the period 1998–2002, based on preliminary figures released by the Transportation Safety Board of Canada.[1] Canadian-registered helicopters were involved in fewer accidents in 2003 than in either 2002 or in the annual average for the five-year period. Similar trends were seen in the numbers of Canadian aircraft involved in fatal accidents (Table 1, page 27). The data include both commercial and private aviation and all categories of aircraft except ultralights.

Fifty-eight people were killed in accidents involving Canadian aircraft in 2003, compared with 50 in 2002 and an average of 65 per year in the 1998–2002 period. There were 44 serious injuries in 2003, compared with 42 in 2002 and an average of 44 per year in the 1998–2002 period.

Non-Canadian-registered aircraft were involved in 29 accidents in Canada in 2003, an increase from 13 the previous year and from an average of 20 per year in the 1998–2002 period. Eight fatalities were recorded in 2003 in Canadian accidents involving non-Canadian aircraft, more than the two in the previous year but fewer than the 1998–2002 annual average of 55. That five-year period included the fatal accident of Swissair Flight 111, in which the airplane struck the Atlantic Ocean near Peggy's Cove, Nova Scotia, on Sept. 2, 1998. [The airplane was destroyed and its 229 occupants were killed in the accident, in which flammable material propagated a fire that began above the cockpit ceiling and spread rapidly, degrading aircraft systems and leading to loss of control of the airplane.]

The 244 accidents involving Canadian airplanes in 2003 included seven airliners, nine commuter aircraft, 35 air taxi (on-demand) aircraft and two corporate aircraft. (Eighteen airplanes involved in commercial aerial work, three state airplanes and 170 "private/other" airplanes were also involved in accidents.) In the 26 fatal accidents to Canadian airplanes in 2003, there were no airliners, commuter aircraft or corporate aircraft; five air taxi aircraft were involved. (Four airplanes involved in commercial aerial work and 17 "private/other" airplanes were also involved in fatal accidents.)

Forty-four Canadian helicopters were involved in accidents in 2003, and three Canadian helicopters were involved in fatal accidents. Both numbers were lower than for 2002 and the annual average in the 1998–2002 period.

Of the 244 Canadian airplanes involved in accidents, 42 were categorized as air transport, eight as business and one as an air ambulance. Other categories accounted for an additional 193 airplanes. The 44 Canadian helicopters involved in accidents included 11 categorized as air transport and one as business; no air ambulance helicopters were involved in accidents. Other categories included 32 helicopters (Table 2, page 28).

Four air transport aircraft (airplanes and

Continued on page 29

Table 1
Canadian Aircraft Accidents and Reportable Incidents, 1998–2003

	Year(s)		
	2003	**2002**	**1998–2002 Average**
Canadian-registered Aircraft Accidents[1]	**297**	**274**	**323**
Airplanes Involved[2]	244	210	263
Airliners	7	6	8
Commuters	9	6	8
Air Taxis	35	41	60
Aerial Work	18	12	17
State	3	4	2
Corporate	2	2	6
Private/Other[3]	170	139	161
Helicopters Involved	44	56	52
Other Aircraft Involved[4]	12	10	13
Fatal Accidents	**31**	**30**	**33**
Airplanes Involved	26	22	25
Airliners	0	0	0
Commuters	0	0	1
Air Taxis	5	4	5
Aerial Work	4	1	1
State	0	2	1
Corporate	0	0	1
Private/Other[3]	17	15	16
Helicopters Involved	3	6	7
Other Aircraft Involved	3	3	3
Fatalities	**58**	**50**	**65**
Serious Injuries	**44**	**42**	**44**
Non-Canadian-registered Aircraft Accidents in Canada	**29**	**13**	**20**
Fatal Accidents	6	1	5
Fatalities	8	2	55
Serious Injuries	3	0	2
All Aircraft: Reportable Incidents	**825**	**865**	**783**
Risk of Collision/Loss of Separation	154	194	182
Declared Emergency	289	280	239
Engine Failure	132	160	164
Smoke/Fire	102	100	97
Collision	15	22	12
Other	133	109	89

Notes:

Figures are preliminary as of Jan. 5, 2004. All five-year averages have been rounded, so totals sometimes do not equal the sum of averages.

[1] Ultralight aircraft are excluded.

[2] Because accidents can involve multiple aircraft, the number of aircraft involved can differ from the total number of accidents.

[3] Other: Contains, but is not limited to, organizations that rent aircraft (e.g., flying schools, flying clubs).

[4] Includes gliders, balloons and gyrocopters.

Source: Transportation Safety Board of Canada

Table 2
Canadian-registered Fixed-wing and Rotary-wing Aircraft Involved in Accidents, 1998–2003, by Type of Operation

	Year(s)		
	2003	**2002**	**1998–2002 Average**
Canadian-registered Aircraft Accidents[1]	**297**	**274**	**323**
Airplanes Involved	244	210	263
Training	34	20	41
Pleasure/Travel	123	102	117
Business	8	6	10
Forest Fire Management	2	2	2
Test/Demonstration/Ferry	5	7	8
Aerial Application	13	6	11
Inspection	1	4	1
Air Transport	42	49	56
Air Ambulance	1	2	2
Other/Unknown	15	12	14
Helicopters Involved	44	56	52
Training	6	9	8
Pleasure/Travel	1	2	2
Business	1	6	3
Forest Fire Management	6	6	5
Test/Demonstration/Ferry	0	5	3
Aerial Application	2	1	1
Inspection	4	1	1
Air Transport	11	14	12
Air Ambulance	0	0	0
Other/Unknown	13	12	15
Fatal Accidents	**31**	**30**	**33**
Airplanes and Helicopters Involved	29	28	32
Training	2	1	3
Pleasure/Travel	15	11	12
Business	0	1	3
Forest Fire Management	2	0	0
Test/Demonstration/Ferry	0	5	2
Aerial Application	1	0	1
Inspection	0	2	0
Air Transport	4	4	5
Air Ambulance	0	0	0
Other/Unknown	5	4	4
Fatalities	**58**	**50**	**65**
Serious Injuries	**44**	**42**	**44**

Notes:
Figures are preliminary as of Jan. 5, 2004. Because accidents can involve multiple aircraft, the number of aircraft involved can differ from the total number of accidents. All five-year averages have been rounded, so totals sometimes do not equal the sum of averages.
[1] Ultralight aircraft are excluded.

Source: Transportation Safety Board of Canada

Table 3
Canadian-registered Aircraft Involved in Incidents, 1998–2003: Selected Reportable Incident Types by First Event

	Year(s)		
	2003	**2002**	**1998–2002 Average**
Risk of Collision/Loss of Separation	**199**	**273**	**246**
Air Proximity	55	65	68
Air Traffic Services Event	106	171	143
Altitude-related	7	8	8
Runway Incursion	11	21	14
Other	20	8	13
Declared Emergency	**226**	**232**	**194**
Landing-gear Failure	31	30	43
Hydraulic Failure	24	34	33
Electrical Failure	10	7	9
Other Component Failure	72	84	64
Other	89	77	45
Engine Failure	**104**	**135**	**135**
Power Failure	38	49	61
Component Failure	59	76	61
Other	7	10	13
Smoke/Fire	**80**	**82**	**80**
Fire/Explosion	56	59	57
Component Failure	24	19	19
Other	0	4	4
Difficulty in Controlling Aircraft	**40**	**28**	**25**
Component Failure	20	4	11
Weather-related	11	7	4
Other	9	17	10

Note: Figures are preliminary as of Jan. 5, 2004. All five-year averages have been rounded, so totals sometimes do not equal the sum of averages.

Source: Transportation Safety Board of Canada

helicopters were grouped together in the fatal-accident category) were involved in fatal accidents in 2003 and the same number in 2002, compared with an annual average of five in the 1998–2002 period. There were no fatal accidents involving business aircraft in 2003, compared with one in 2002 and an annual average of three in the 1998–2002 period. The fatal-accident total in all categories was 29 in 2003, 28 in 2002 and an annual average of 33 in the 1998–2002 period (Table 2).

For all Canadian-registered aircraft involved in reportable incidents in 2003 (a total of 649), the type of first event in the incident was categorized (Table 3). "Declared emergency" was the category with the most aircraft involved (226, compared with 232 in 2002 and an annual average of 194 in the 1998–2002 period). Within that category in 2003, there were 31 aircraft involved in reportable incidents of landing gear failure, 24 in incidents of hydraulic failure, 10 in incidents of electrical failure, 72 in incidents of other component failure and 89 in "other" incidents.

"Risk of collision/loss of separation" was the incident type with the second-largest number of aircraft involved in 2003 (199, compared with 273 aircraft in 2002 and an average of 246 aircraft per year in the 1998–2002 period). Within that category in 2003, 106 aircraft were involved in reportable incidents described as "air traffic services events" (compared with 171 aircraft in 2002 and an average of 143 aircraft per year in the 1998–2002 period). ■

[FSF editorial note: The data in this article are derived from tables published on the Transportation Safety Board of Canada Internet site at <www.tsb.gc.ca/en/stats/air/2003_dec/index.asp>.]

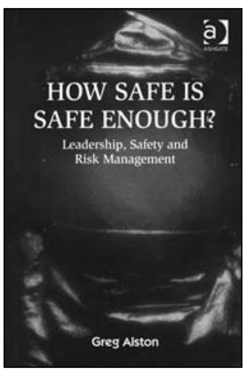
Note

1. All data were preliminary as of Jan. 5, 2004.

Leadership Is Essential to "Winning the Risk Game"

Leaders often make the difference in the outcome — if they understand the rules of the risk-management game, suggests the author of *How Safe Is Safe Enough*?

— FSF LIBRARY STAFF



Books

How Safe Is Safe Enough? Leadership, Safety and Risk Management. Alston, Greg. Aldershot, England: Ashgate Publishing, 2003. 115 pp. Figures, bibliography, index.

"An organization is safe enough when the leader seeks out modern safety processes and makes the effort to identify every possible hazard, and then strives to eliminate, control or reduce the associated risks through training, procedures and technology to the point that operations do not accept any unnecessary risks," says the author in answer to the question he poses in his book's title.

The book discusses risk management using the metaphor of a game that can be won or lost. As in most games involving multiple individuals, the author says, leadership often makes the difference between winning and losing. "Winning the risk game is what safety is all about," he says. "I have watched over safety teams and found that those with committed support of senior leaders tend to win. However, leaders at all levels play a critical role in determining the correct level of safety."

Specific leadership behaviors provide the essential elements of winning the game, the author says. The author cites the following leadership tasks:

- "*Lead* the risk game;
- "Know the *costs of losing* the risk game;
- "Comprehend *universal probabilities*, and the effects of *human intervention*;
- "Understand the basic principles of *risk management*;
- "Understand the basics and appreciate the value of the *system safety* process;
- "Be familiar with the elements of *organizational risk*;
- "Appreciate the value of *personal risk management*;
- "Get involved in the organization's *safety program*; [and,]
- "Be open to positive *change*."

Each of the subjects is examined in its own chapter in the book.

Achieving zero accidents is possible, the author says, but there are a number of obstacles to the goal, of which human factors is the greatest.

"We as humans are subject to human error and psychological and physiological frailties such as fatigue, perceptions, stress, complacency and distraction," he says. "While we can improve our performance with sound training and mentoring, we cannot change our basic condition. We can, however, change the conditions in which we work to protect ourselves from our less-than-perfect states. Physical safeguards, personal protective equipment, systems safety, safety procedures and careful supervision help 'safe-up' our work environments and enhance our journey toward zero mishaps."

Stepping Up to ISO 9004:2000: A Practical Guide for Creating a World-class Organization. Westcott, Russell T. Chico, California, U.S.: Paton Press, 2003. 184 pp. Figures, tables, appendixes, glossary, index.

The book is designed to help organizations that want to go beyond the requirements of ISO [International Organization for Standardization] 9001:1994 or ISO 9001:2000 for quality management systems (QMSs). It focuses on "raising an organization's business practices from minimum requirements to best-practices level — and ultimately to world-class status — rather than on addressing deficiencies in meeting basic requirements," the author writes.

The book discusses key QMS issues, including strategic direction and implementing action plans; focusing on the customer; focusing on resource management; assessing and managing risk; focusing on product realization; focusing on measurement and analysis; focusing on continual improvement; benchmarking; and applying project-management tools to achieve continual improvement.

Effective risk management, the author writes, involves five steps:

- Planning how the organization will identify its exposures to loss; will quantify the potential financial risks and nonfinancial risks; will examine the feasibility of alternative risk-management techniques; and will select the best risk-management techniques;

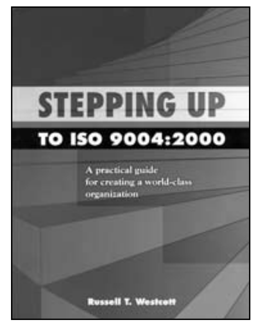
- Testing the selected risk-management techniques;

- Checking the techniques' effectiveness, making necessary adjustments or selecting a new alternative;

- Acting to implement the full process and monitoring the techniques for adequacy; and,

- Improving the techniques.

"Although it's often easy to see what could have been done after a loss occurs, seeing what could happen that would adversely affect your organization — and then taking steps to eliminate or minimize those vulnerabilities — is more difficult," the author says. "However, techniques and tools exist for identifying and analyzing loss exposures." The focus is on risks to the organization itself rather than operational risks, but the methodologies discussed could stimulate thought and discussion at the operational level as well.



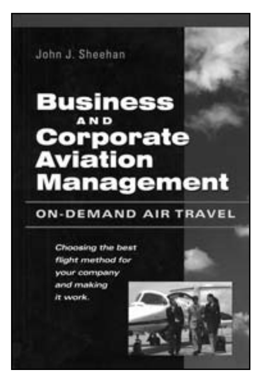
Business and Corporate Aviation Management. Sheehan, John J. New York, New York, U.S.: McGraw-Hill, 2003. 376 pp. Figures, tables, glossary, appendixes, index.

Although they provide safe and reliable public transportation, airlines can be inconvenient for business travel involving an organization's key personnel. Airlines that operate on the hub-and-spoke system do not provide direct point-to-point transportation to many destinations, necessitating multiple-segment trips and sometimes time-consuming layovers between segments. Furthermore, flights to destinations with relatively little passenger traffic tend to be scheduled infrequently.

Business aviation — whether in the form of chartered aircraft, fractional aircraft ownership or full aircraft ownership — is widely established as an answer to the requirements of many companies.

This book, says the author, was written for two audiences:

- "Individuals seeking information about how to get into the on-demand air transportation business, whether for business or personal reasons; [and,]



- "Flight department managers, their bosses and those who would become flight department managers."

The job of managing a flight department (large or small) usually is given to a senior pilot, but experience as a pilot does not necessarily prepare a person for management, the author says. *Business and Corporate Aviation Management* is intended to help overcome such a knowledge gap. "While the book contains some theory, the majority of its contents are very practical, based on a variety of observations and insights gained from my work with on-demand flight operations," the author says. "Experiences gained from working with airlines, repair stations and air taxi operations are used liberally throughout as well."

Chapters discuss selecting from the options in business air transportation modes; how to begin the various types of business aviation operations; planning, administrative, human resources and financial aspects of management; the flight department manager as a business executive; day-to-day operations; maintenance; and safety. A section is devoted to the small flight department that operates one aircraft or two aircraft, which "is the most common form of flight department and the type with the greatest burden, because of [its] many tasks and few people available to complete them."

The foundation of a safety culture includes "senior pilots and [maintenance technicians] who go by the book, take the conservative approach and comment on unsafe and potentially unsafe practices they observe."

Other important principles are the following:

- "Recurring references to standards;
- "Constant training;
- "Required reading of safety materials;
- "Review of standardization, regulatory and procedural materials;
- "Spontaneous discussions of aircraft systems, procedures and regulations; [and,]
- "Spot inspections of facilities and records."

The cliché that safety is everyone's business must not permit safety responsibility to become so diffuse that it is nobody's business in particular. The author recommends that there be specific assignments to monitor and to report on various aspects of safety, such as passenger policies, air traffic control, fueling and hazardous materials.

The individual who becomes aware of a problem must take initiative. "For example, if the standard operating procedure (SOP) regarding checklist usage is unrealistic or undoable on quick-turnaround flights, the person who first realizes this should initiate action to change it," the author says. "This requires communicating the perceived fault to peers and supervisors alike. Moreover, it means devising a new procedure, testing it and *selling* it to the rest of the department."

Passenger Behaviour. Bor, Robert (ed.). Aldershot, England: Ashgate Publishing, 2003. 316 pp. Figures, tables, references, index.

The psychological aspects of piloting have been widely studied, and those of cabin crew duty have received attention as well. But, the editor says, this is the first current text about passenger behavior. He says that it is designed to be useful not only for cabin crewmembers but for everyone who interacts with the traveling public — ground staff, airline managers, airport managers, aviation safety specialists, aerospace medical personnel and aircraft designers.

The anthology, which includes papers by specialists in psychology, travel medicine, fire-safety research and other disciplines, examines but does not emphasize dramatic phenomena such as "air rage" and hijacking. Subjects range from medical issues and psychological issues (e.g., flying-related stress, fear of flying, psychiatric difficulties among passengers, the physiological effects of the cabin environment, and travel fatigue and jet lag) to safety issues (e.g., passenger behavior in emergency situations and passenger attention to safety information).

"Humans have not evolved naturally to fly," the editor says. "Even the most seasoned air travelers appear to carry an 'emotional charge' when they fly. They may experience a range of both pleasant and unpleasant feelings, ranging from claustrophobia, frustration, fear and elation to anxiety stemming from separation from a loved one, relief, disorientation or a sense of anticipation and adventure."

Scientific research about passenger behavior is hindered by a number of factors, including "a reluctance by airlines to permit research to be undertaken in a commercial and customer-sensitive environment, ethical considerations, the exceptional cost of such research and possible safety implications of such research. " In a simulated cabin environment, it is difficult to replicate all of the psychological issues present among passengers in an actual flight.

Nevertheless, the editor says, "It is hoped that this book will help reflect what is already known about passenger behavior and also point the way forward for future research."

United States Air Force Museum. Revised edition. Wright-Patterson Air Force Base, Ohio, U.S.: The Air Force Museum Foundation (AFMF), 2003. 192 pp. Photographs, index. Available from AFMF.*

The U.S. Air Force Museum (established in 1923) is known as the oldest and largest military aviation museum in the world and "presents the history of the United States Air Force and predecessor organizations by exhibiting aircraft, missiles and artifacts associated with important events and eras, notable achievements and aeronautical developments," says the book's introduction.

The museum's collection contains historic aircraft, reproductions of aircraft and test prototypes. The book presents black-and-white photographs and color photographs of more than 185 aircraft from the museum's collection. Photos are accompanied by aircraft specifications, performance data and brief historical descriptions. Several missiles and spacecraft also are featured.

The historical range of photographs begins with a reproduction of the 1909 Wright Military Flyer designed for the U.S. Signal Corps and ends with unmanned aerial vehicles.

World War I–era, World War II–era and Cold War aircraft from many countries are represented. Among them are the Fokker Dr. I triplane (1917), the type flown by the ace fighter pilot Manfred von Richthofen; the German Halberstadt CL IV biplane (1918), introduced to attack Allied positions in the last great German offensive of World War I; Italy's Caproni CA.36 from World War I, a three-engined bomber; Great Britain's Sopwith F-1 Camel (1917), the most famous fighter plane of World War I, and Hawker Hurricane MKIIA (1937), a Royal Air Force mainstay in the Battle of Britain; Japan's Yokosuka MXY7-K1 (1940s), used to train the pilots of the Ohka *kamikaze* suicide rocket-bomb; and the Soviet Union's Mikoyan-Gurevich MiG-15 (1949), frequently used in combat in the Korean War.

Sections of color plates include "Classic Fighters," "Classic Trainers," "Classic Bombers," "Classic Cargo Planes," "[U.S.] Presidential Aircraft" and "X-planes" (experimental aircraft).

Reports

Validation of the JANUS Technique: Causal Factors of Human Error in Operational Errors. Pounds, Julia; Isaac, Anne. U.S. Federal Aviation Administration (FAA) Office of Aerospace Medicine (OAM). DOT/FAA/AM-03/21. December 2003. 12 pp. Tables, references. Available on the Internet at <www.cami.jccbi.gov> or from NTIS.**

Human error has been identified as a dominant risk in aviation and other safety-oriented industries. For air traffic control (ATC) and air traffic management (ATM), it is important to understand factors that lead to human errors within current systems, particularly those contributing to violations of separation standards, the report says.

Before human error can be prevented, an understanding is needed of when and where it occurs in existing systems, as well as of the system variables that contribute to it. To reach such an understanding, meaningful data from individuals and ATM systems must be captured and analyzed.

This report describes the evaluation of one technique, JANUS, to determine its suitability for identifying incident causal factors in relation to current investigation methods. [JANUS is not an acronym but refers to the ancient Roman god of doors and gates, with a double-faced head looking simultaneously forward and back. The name was adopted to symbolize looking at types of past incidents and at how they can be avoided in the future.] "Strengths of the JANUS technique include use of a structured-interview process so that psychological errors contributing to the air traffic controller's behavior can be identified and lessons learned from the incident," says the report.

Scientists from the European Organization for the Safety of Air Navigation (Eurocontrol) and from FAA worked with ATC personnel to analyze incidents on file using the JANUS taxonomy and the JANUS structured-interview process. The JANUS technique examines each incident as potentially having multiple linking events and analyzes each event or link separately. Researchers found that the JANUS technique appeared to be more sensitive, useful, comprehensive and practical than current processes to identify incident causal factors.

This study represents one phase of a research project, "Management and Reduction of Human Error in Air Traffic Management," conducted jointly by Eurocontrol's Human Factors and Manpower Unit and FAA's Civil Aerospace Medical Institute.

Regulatory Materials

Aviation Maintenance Human Factors: Guidance Material on the U.K. CAA Interpretation of Part-145 Human Factors and Error Management Requirements. U.K. Civil Aviation Authority (CAA). Civil Aviation Publication (CAP) 716. Issue 2. Dec. 18, 2003. 300 pp. Available on the Internet at <www.caa.co.uk> or from Documedia.***

U.K. CAA says, "An organization with a good safety culture is one which has managed to successfully institutionalize safety as a fundamental value of the organization, with personnel at every level in the organization sharing a common commitment to safety."

The publication provides details of the CAA's interpretation of European Joint Aviation Requirements (JARs) Part 145 and European Aviation Safety Agency (EASA) Part 145. The interpretation primarily applies to large aircraft-maintenance organizations approved under Part 145 and provides practical guidance material for applying best practices in human factors within an organization's procedures. "The emphasis is on practical guidance material for real-world situations, acknowledging (but not condoning) the fact that sometimes people fail to comply with procedures, albeit often with the best of intentions," says the CAA. "It recognizes that organizations operate within a competitive commercial environment and concentrates upon risk and error *management* rather than risk and error *elimination*."

Some of the major topics addressed are elements of a human factors program; facilities, tools and work environments; maintenance-error-management system; audits; worker fitness; professionalism and integrity; communications and teamwork; and human factors training for maintenance personnel. The publication is designed to be used as a basis for training, but not as a training text.

Guidance material, much of it based on industry experience, may be tailored to suit the size of an organization and the nature of its corporate business. Examples are included of a company's safety policy and a company's disciplinary policy; a list of safety accountabilities for management staff; a checklist for assessing attitudes and practices of an organization; and sample questionnaires on issues that could affect aviation safety within a maintenance organization. The document also contains a copy of "JAA Maintenance Human Factors Working Group Report" and International Civil Aviation Organization standards for human factors in maintenance.

Appendix D contains brief summaries of high-profile accidents and high-profile incidents that involved maintenance human factors problems. Summary accident data and incident data collected from analytical reviews of the past 20 years are presented in tables to illustrate causes or contributory factors.

"A good safety culture needs to be nurtured, and is not something which can be put in place overnight, or with a training course alone," says the CAA. "It can be improved in the short term by putting staff through a training course dealing with the elements of a safety culture. However, the improvement will only be sustained if the types of behaviors conducive to safety are rewarded and poor safety behavior is not condoned, or even punished (in the extreme cases). … A good safety culture is based on what actually goes on within an organization on a day-to-day basis, and not on rhetoric or superficial, short-term safety initiatives."

Turbojet, Turboprop, and Turbofan Engine Induction System Icing and Ice Ingestion. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 20-147. Feb. 2, 2004. Tables, attachment. 25 pp. Available from GPO.****

This AC provides nonmandatory guidance and acceptable methods for demonstrating compliance with U.S. Federal Aviation Regulations (FARs) requirements for engine-induction-system icing and engine-ice ingestion. FAA says that the primary purpose of the AC is to reduce inconsistencies and eventual surprises encountered by manufacturers of turbojet engines, turboprop engines and turbofan engines certified under FARs Part 33 and installed in normal, utility, acrobatic and commuter category airplanes certified under Part 23 and transport category airplanes certified under Part 25. The AC does not address the installation of turboshaft engines in rotary wing aircraft; AC 20-73, *Aircraft Icing Protection*, is the primary AC for these installations.

The AC includes recommended standard test conditions to demonstrate that no adverse effects on engine operation or serious loss of power or thrust (e.g., nonrecoverable or repeated surge, stall, rollback or flameout) occur during flight in icing conditions. The AC said that 30 years of certification experience and hundreds of millions of hours of service experience have shown that the recommended test conditions provide an adequate and consistent basis for engine-icing certification.

The AC says that engine operation should be reliable, uninterrupted and without any significant adverse effects during the following recommended test conditions:

- Operation for at least five minutes at the takeoff-power setting, followed by operation for at least 10 minutes at 75 percent maximum continuous power (MCP), at 50 percent MCP and at the flight-idle setting in a glaze-icing condition (a liquid water content [LWC] of at least two grams per cubic meter, an inlet temperature of 23 degrees Fahrenheit [F] and a mean effective water droplet diameter of 22 microns);

- Operation for at least five minutes at the takeoff-power setting, followed by operation for at least 10 minutes at 75 percent MCP, at 50 percent MCP and at the flight-idle setting in a rime-icing condition (an LWC of at least one gram per cubic meter, an inlet temperature of –4 degrees F and a mean effective water droplet diameter of 15 microns); and,

- Engine operation at the ground-idle setting for at least 30 minutes, followed by acceleration to the takeoff-power setting in a ground-fog-icing condition (an LWC of at least 0.3 gram per cubic meter, an inlet temperature of 15 degrees F to 30 degrees F and a mean effective water droplet diameter of 20 microns).

FAA includes recommended test conditions for prolonged engine operation (at least 45 minutes) in rime icing and mixed (rime and glaze) icing. The mixed-icing condition must be alternated between an LWC of 0.3 gram per cubic meter and a mean effective droplet diameter of 15 microns to 20 microns, and an LWC of 1.7 grams per cubic meter and a mean effective droplet diameter of 20 microns; with inlet temperatures of 14 degrees F for turbofan engines and 6 degrees F for turboprop engines.

The AC says that during the tests, ice should not accumulate to an extent that it adversely affects engine operation, no sustained power loss should occur and, except for specific circumstances, no engine damage should occur.

Aircraft Collide in Gate Area

The flight crew of one of the Airbus A320s said that ground personnel had motioned to them to indicate the wing tip clearance distance. One ground crewmember, however, said that he had given the crew "the hold sign."

— FSF EDITORIAL STAFF

The following information provides an awareness of problems through which such occurrences may be prevented in the future. Accident/incident briefs are based on preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be entirely accurate.

AIR CARRIER

Captain Cited Communications Problems

Airbus A320. Minor damage. No injuries. — Airbus A320. Minor damage. No injuries.

Night visual meteorological conditions prevailed as the two airplanes were being prepared to leave the gate area at an airport in the United States.

The captain of the first airplane said that during pushback, he had observed the second airplane being pushed back from its gate toward his airplane's position and that he relayed his concern to ground personnel "but did not receive a clear response." He said that as the second airplane approached, two people from that airplane's push crew ran out "apparently to get a better view." "Both airplanes were finally stopped in close proximity," he said. "We were positioned to the east of our push line, toward the other aircraft."

He and his first officer started their airplane's engines, and the ground crew disconnected their tug with a salute and a "release from guidance for a left turn out."

He said that a member of the second airplane's ground crew "was looking toward us and holding his right hand overhead and with his left arm out and slightly raised, indicating the wing tip clearance distance." The captain said that he taxied the airplane forward slowly at idle thrust and that after a short distance, the wing tips of the two airplanes collided. He said that communications with the tug had been difficult because of "language and nonstandard phraseology" used by the pushback crew.

The first officer on the same airplane said that he also observed the ground crewmember "standing in front [of] and between the two airplanes, looking at us with wand raised and other arm held out horizontally indicating wing clearance. … With wingman guidance and a visual check, I told the captain we were cleared on the right. We started to move, and I glanced forward. When I looked back out to the right, the wing walker was gone, and then the wing tips made contact."

A ground crewmember from the other airplane said that he had walked the wing on the same side as the first officer and that after the push-back was stopped by a ground crewmember on the captain's side of the airplane, he "went around to see what was happening." He observed the wings of the airplanes 20 feet to 30 feet (six meters to nine meters) apart. He said that he "looked at the first officer … and gave him the hold sign." He then walked toward the tug operator, and as they discussed the airplanes' positions, the airplane "proceeded to move and clipped the wing," he said.

Smoke Prompts Crew's Mayday Declaration

BAE Systems BAE 146. No damage. No injuries.

The airplane was being flown from England to France and was about 40 nautical miles (74 kilometers) from its destination when the first officer smelled smoke and saw "a faint haze" on his side of the flight deck. The crew declared mayday, a distress condition, and received radar vectors to the destination airport, where they conducted an uneventful landing.

The airplane was taxied to the gate, and passengers disembarked normally. An examination by maintenance personnel found that oil had leaked from the no. 1 air-conditioning pack because of an oil-seal failure in the auxiliary power unit (APU) and that there had been a "smoky oven" in the galley. The APU was removed for further examination and an overhaul.

Tire Fails During Landing

McDonnell Douglas DC-10. Minor damage. No injuries.

After a landing at an airport in England following a flight from the Canary Islands, the flight crew was told by air traffic control (ATC) that debris had been found on the runway. Ground personnel determined that the no. 8 main-wheel tire, which was still inflated, had lost its tread and that there was a hole in an access panel in the wing near the right-main landing gear.

The tire manufacturer said that the failure of the tire, which was on its fourth retread, resulted from "premature fatigue or over-deflection," which led to a leak of the tire's inner liner and allowed nitrogen to enter the casing more quickly than the nitrogen could be vented. The resulting increase in pressure "either caused or inflated a separation between the plies," the incident report said.

After the incident, the manufacturer planned to examine tires at the third retread to determine whether fatigue was developing.

First Officer Incapacitated After Landing

Airbus A320. No damage. One fatality.

Day visual meteorological conditions prevailed for the charter flight from Turkey to Denmark. The first officer conducted a landing that the accident report described as "uneventful, until the landing roll."

The first officer twice failed to make a callout to the captain in accordance with the operator's standard operating procedures, and the captain twice warned him of the missed callout. Then the captain "observed that the first officer was incapacitated" and took control of the airplane, taxied it to the gate and requested medical assistance from the airport air traffic control tower.

The first officer was pronounced dead at a local hospital. A medical report said that he probably died because of an embolism (sudden blockage of a blood vessel by something that had been circulating in the blood) in the lungs and heart.

Cabin Crewmember Injured by Turbulence

Avions de Transport Régional ATR 42-300. No damage. One serious injury.

The airplane was being flown in clouds on an evening flight from Wales to Ireland. A weather forecast predicted turbulence associated with passage of a front, but the crew of another aircraft being flown along the same route said that they had encountered no turbulence.

About 50 nautical miles (93 kilometers) from the destination airport, the airplane was flown into turbulence, and the captain turned on seat-belt signs in the cabin. The cabin crewmember secured the cabin. Because turbulence was light, she remained standing in the galley. Seconds later, the airplane encountered severe turbulence, which threw the cabin crewmember across the galley, into the cabin ceiling and a bulkhead and then onto the floor. With difficulty, she moved to her seat and fastened her seat belt. She used the interphone to tell the captain what had happened and later made a pre-landing announcement to passengers. She was taken to a hospital with skeletal muscular injuries.

The accident report said, "It is understandable that experiencing only very light turbulence, the crewmember chose to remain standing. However, the potentially rapid onset and severe nature of some turbulence encounters pose a danger to anyone remaining unsecured. The danger is compounded if, as on this occasion, there is only one cabin crewmember on board whose incapacitation through injury could have serious consequences in any subsequent aircraft emergency."

Electrical Failure Prompts Call for Improved Checklists

BAE Systems ATP. No damage. No injuries.

Night instrument meteorological conditions prevailed for the approach to an airport in Sweden, when the left electrical system failed and the pilot's flight instruments and navigational systems (electronic flight instrument systems) stopped operating. In addition, the main emergency light blinked, and the master caution horn sounded. The incident report said that the flight crew did not believe that any section of the emergency checklist was relevant to the problem, so they declared an emergency and received radar vectors from air traffic control for landing.

The accident report said that an investigation found that the power failure was caused by the simultaneous occurrence of two independent faults in the electrical system. The flight crew probably could have restored full electrical function by "cross-connecting from the right-hand electrical system," the report said. The report said that this solution "to some extent emerges from the emergency checklist"; nevertheless, the checklist was "not user-friendly and does not represent the natural aid for pilots to identify a possible fault and take the most suitable steps from the point of view of flight safety."

The report recommended that the Swedish Civil Aviation Administration, in connection with its issuance of air operator certificates, "observe specially the arrangement of emergency checklists from the point of view of comprehensibility and user-friendliness."

Airplane Strikes Ground During Takeoff in Snow

Socata TBM 700. Substantial damage. No injuries.

Night instrument meteorological conditions prevailed for the flight from an airport in the United States, and an instrument flight rules flight plan had been filed. The pilot said that the takeoff roll on the snow-covered runway appeared to be normal.

Four seconds to five seconds after liftoff, the airplane began to shake. The pilot said that indications on all engine instruments were normal, that the airspeed was steady at 110 knots and that the airplane was not climbing. He said that he tried to fly the airplane straight ahead in a climb and that he increased the pitch angle as airspeed decreased to about 80 knots; then the stall-warning horn sounded. The pilot said that he decreased the airplane's pitch attitude and flew the airplane with wings level just above the stall speed. A preliminary report said that the airplane "came to rest approximately one [nautical] mile [1.9 kilometers] southeast of the airport in a construction site."

The pilot said that during start-up procedures, because snow was falling, "all deice systems except the wing boots" were activated. The pilot had not deiced the wings "because the snow was blowing off the top of the wing," the report said.

After the accident, rough granular ice was observed atop both wings; the report said that "the shape of the ice defined the shape of the fuel tank in each wing."

The airplane's fuel tanks had been topped off about two hours before the flight. The fuel was obtained from a truck that had been kept in a heated hangar; the airplane had been kept in an unheated hangar, with the hangar doors open.

Wind Shift Reported After Runway Overrun

Raytheon Corporate Jets 390 Premier I. Substantial damage. No injuries.

Visual meteorological conditions prevailed for the approach and landing at an airport in the United States. After landing on Runway 7, the airplane overran the runway.

A routine weather report issued four minutes before the accident said that winds were from 160 degrees at 15 knots, with gusts to 20 knots. A special weather report issued 16 minutes after the accident showed winds from 190 degrees at 14 knots and included a statement that a wind shift had occurred four minutes before the accident. The report defined wind shift as a change of wind direction of 45 degrees or more in less than 15 minutes with wind speed of at least 10 knots throughout the wind shift.

Airplane Strikes Ground After Illumination of Low-fuel Light

Piper Aerostar 600. Substantial damage. One serious injury, one minor injury.

The airplane was being flown on a series of calibration flights involving radio navigation aids at an airport in Bangladesh. The first two flights were uneventful, but during the third flight, the flight crew observed that the low-fuel-level warning light had illuminated. Immediately after they told air traffic control that they planned to return to the airport, the airplane struck the ground.

The accident report said that the cause of the accident was the "noncompliance by the flight crew with the approved emergency operating procedures of the … flight manual (i.e., selection of [the] fuel-supply selector switch of both the engines to [the cross-feed] position when [the] low-fuel-warning light illuminated, thereby connecting both [engines'] fuel supply to depleted wing tanks), resulting in fuel starvation of … both engines, though the remaining fuel in the fuselage tank was adequate for making a safe landing."

Accelerated Stall Results in Hard Landing

Gulfstream American GA-7 Cougar. Substantial damage. No injuries.

The midday flight was being conducted from an airport in England to renew the pilot's single-pilot multi-engine aircraft rating. The pilot had 4,925 flight hours, including one flight hour in type.

The pilot had completed a number of maneuvers away from the airport and had flown the airplane back to the airport, where he had flown two takeoffs and landings. The accident report said that, on both landings, the aircraft had touched down "well down the runway, and prior to flying the third and final circuit, the instructor reminded the handling pilot of the correct approach speed."

During the initial stages of the third approach, the airspeed was correct; the airspeed decreased, however, as the airplane neared the runway.

"As the aircraft crossed the threshold, the handling pilot pulled back on the control column, and almost immediately, the stall-warning horn sounded, the right wing dropped, and the aircraft landed very heavily on the right-main landing gear," the report said.

The instructor was unaware of damage until after the airplane was stopped. He said that the accelerated stall and wing drop had occurred because of the slow airspeed as the airplane was flown across the runway threshold and because the pilot raised the airplane's nose sharply during the landing flare.

Jet Blast Damages Parked Airplane

Cessna 172. Substantial damage. No injuries. — Boeing 767-300. No damage. No injuries.

As the flight crew of the Boeing 767 prepared to taxi the airplane from the apron (ramp) at an airport in Zanzibar to the runway for a midday takeoff, a ground crewmember cautioned the flight crew about smaller aircraft parked elsewhere on the apron.

The flight crew taxied the B-767 until it was abeam the Cessna and then turned the airplane right to enter a taxiway. The B-767 stopped momentarily, and as power was increased to resume taxiing, jet blast from the engines struck the parked Cessna. The accident report said that the jet blast "caused the aircraft to become momentarily airborne, subsequent to which it landed on the nose and settled on its back."

As a result of the accident, the Accident Investigation Branch of the Tanzania Ministry of Communications and Transport, which investigated the accident, recommended that the parking area for smaller aircraft be moved to another location.

ROTORCRAFT

Disconnection of Hydraulic System May Have Caused Control Problem

Eurocopter AS 350B. Minor damage. No injuries.

In preparation for departure from an area in England bordered by trees on two sides and by a house and a lake, the pilot conducted a normal start, followed by after-start checks that included two checks of the hydraulic system. Both hydraulic system checks — which routinely involve sounding of the warning horn and illumination of the "HYD" caption (annunicator light) on the central warning panel — were satisfactory. After they were completed, the pilot selected the hydraulic-isolation switch to restore normal hydraulic power, but the "HYD" caption remained illuminated until he cycled the switch two times.

As the pilot began to lift the helicopter into a hover and to maneuver toward the lake to begin a departure, he felt the controls become stiff and observed that the "HYD" caption was again illuminated; the warning horn did not sound, however. The pilot maneuvered the helicopter to the departure site and conducted a landing; during the process, the helicopter's tail struck branches, and the tail rotor was damaged.

The accident report said that the hydraulic system apparently had become disconnected from the flight controls before takeoff.

Helicopter Strikes Ground During Antarctic Flight

Bell 407. Destroyed. Two serious injuries.

The helicopter was being flown in an attempt to circumnavigate the earth. On the morning of the accident, the crew had received a weather briefing in Antarctica, about 600 nautical miles (1,111 kilometers) north of the South Pole, from a professional pilot who had years of experience flying in the Antarctic.

At departure, skies were clear, and the crew flew the helicopter at 1,000 feet above ground level (AGL) for about 240 nautical miles (444 kilometers), when cloud cover increased. Visibility was good until the helicopter suddenly entered whiteout conditions. The crew tried unsuccessfully to reverse course and then decided to attempt a landing.

"As the helicopter passed through about 200 feet AGL, the crew were still unable to see the surface, and the commander began to slow the helicopter from 60 knots," the accident report said. "At a speed of about 45 knots and just as the nonhandling pilot called a radio altitude of

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