FLIGHT SAFETY FOUNDATION

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FLIGHT SAFETY DIGEST

Loss of Control: Returning From Beyond The Envelope

Targeting Aviation's No. 1 Killer

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In This Issue

Loss of Control: Returning From Beyond the Envelope

Cover photo: Learjet 25B variable-stability in-flight simulator. (General Dynamics)

Flight Safety Foundation is an international membership organization dedicated to the continuous improvement of aviation safety. Nonprofit and independent, the Foundation was launched officially in 1947 in response to the aviation industry's need for a neutral clearinghouse to disseminate objective safety information, and for a credible and knowledgeable body that would identify threats to safety, analyze the problems and recommend practical solutions to them. Since its beginning, the Foundation has acted in the public interest to produce positive influence on aviation safety. Today, the Foundation provides leadership to more than 900 member organizations in more than 145 countries.

Airplane Upset Recovery Training: A Line Pilot's Perspective

To reduce loss of control accidents, the U.S. government has funded a program to provide airplane-upset-recovery training for 2,000 airline pilots. The training is conducted in an aerobatic single-engine airplane and in a multi-engine jet modified as a variable-stability in-flight simulator.

Capt. Robert L. Sumwalt III

Loss of control (LOC) is a leading cause of airplane accidents and fatalities in commercial and corporate flight operations. Data compiled by Boeing Commercial Airplanes show that more people perished in LOC accidents than in any other type of accident that occurred in air carrier operations worldwide during the last decade (see "More Than Half of Large Commercial Jet Accidents in 2002 Occurred During Approach and Landing," page 33).[1]

U.S. Federal Aviation Administration (FAA) data show that in 1996 through 2002, LOC in flight was the leading type of event in accidents involving U.S. corporate airplanes (Figure 1, page 2).[2]

There are several initiatives underway to reduce LOC accidents. From 1996 to 1998, three dozen organizations — including Flight Safety Foundation, manufacturers, international air carriers, pilot organizations, flight-training organizations and government and regulatory agencies — worked together to develop the *Airplane Upset Recovery Training Aid*, which includes approximately 160 pages of text and two videotapes.[3] The training aid was developed primarily to reduce LOC accidents caused by swept-wing airplane upsets. Distribution of the training aid began in August 1998. The training aid currently is being updated, and the updated version should be published within the next few months.[4]

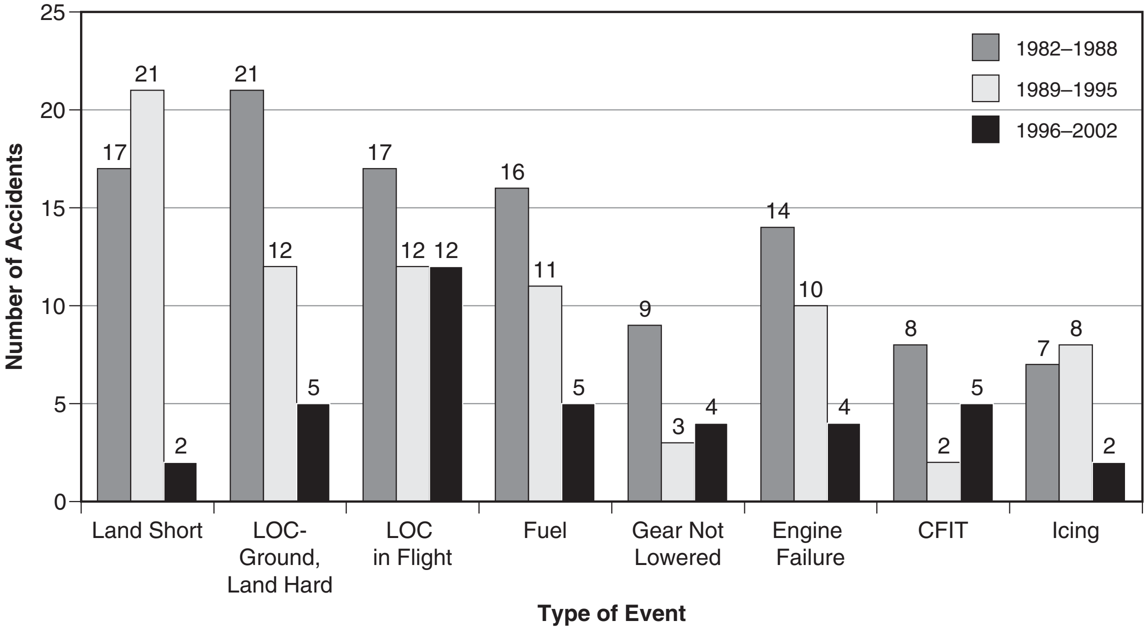
An upset occurs when the pitch attitude, bank angle or airspeed of an airplane in flight unintentionally exceeds the values normally experienced in line operations or training. The training aid says, "While specific values may vary among airplane models, the following unintentional conditions generally describe an airplane upset:

- "Pitch attitude greater than 25 degrees nose-up;
- "Pitch attitude greater than 10 degrees nose-down;
- "Bank angle greater than 45 degrees; [or,]
- "Within the above parameters but flying at airspeeds inappropriate for the conditions."

The training aid includes data from a U.S. National Transportation Safety Board (NTSB) analysis of 20 LOC accidents involving transport category airplanes from 1986 to 1996 that identified stalls as the leading cause of the accidents (Figure 2, page 2).

In 1997, U.S. government organizations and industry organizations formed the "Safer Skies" initiative to reduce general aviation fatalities and commercial aviation fatalities.[5] The Safer Skies teams used a data-driven method to ensure

Corporate Aircraft Accidents by Type of Event, Seven-year Periods, 1982–2002



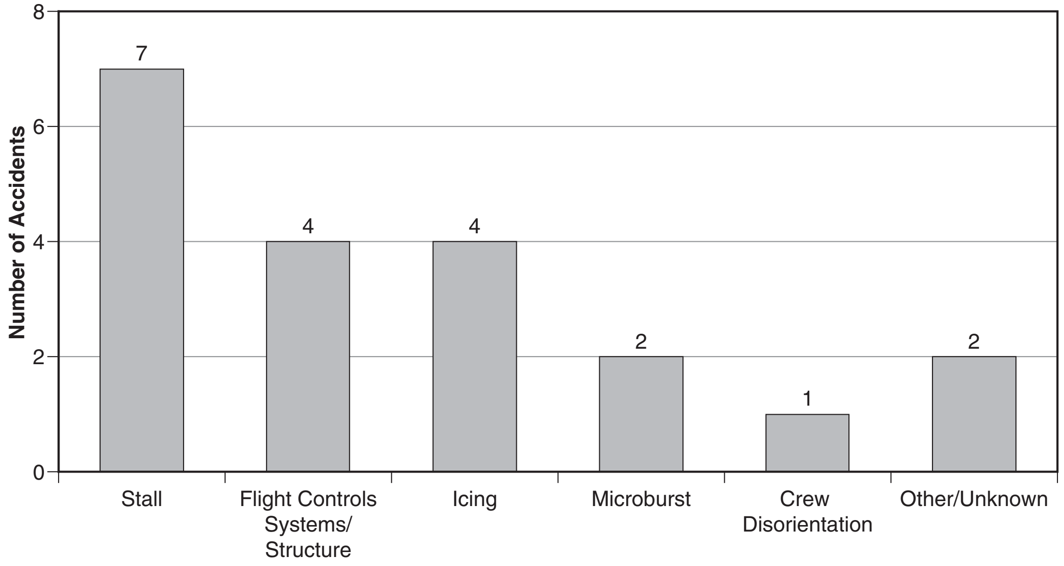
Notes: Landing short includes a small number of CFIT-into-level-ground accidents. LOC in flight excludes fuel systems failure, etc., unless emergencies were mishandled. Some double-counting.

LOC = Loss of control CFIT = Controlled flight into terrain

Source: Bob Matthews, U.S. Federal Aviation Administration

Figure 1

Causes of 20 Loss-of-control Accidents Involving Transport Category Aircraft 1986–1996



Source: *Airplane Upset Recovery Training Aid*

Figure 2

that their efforts were focused on areas that would have the greatest impact on improving flight safety. LOC was common to the general aviation and commercial aviation agendas, along with controlled flight into terrain (CFIT) and runway incursions.[6,7]

Both the general aviation team and the commercial aviation team determined that there are several ways to improve the LOC accident rate. Intervention strategies identified by the commercial team included the following:[8]

- Improved standard operating procedures (SOPs);
- Risk assessment and management;
- Training in human factors and automation;
- Improved autoflight features, such as flight-envelope protection to help keep the airplane within the normal flight envelope;
- Better alerting and display features;
- Improved criteria for flight in icing conditions; and,
- Advanced maneuvers training.

Format of Upset Recovery Training Varies

For the purposes of this article, advanced maneuvers training is synonymous with upset recovery training (URT), which the training aid characterized as an investment.

"There will be additional costs associated with airplane [URT]; however, it is anticipated that the return on the investment will be a reduction in airplane accidents," said the training aid.

In the past decade, several air carriers implemented URT. The format of this training varies. Some air carriers provide extensive reading material, classroom instruction and frequent practice and training in ground-based flight simulators. Conversely, some air carriers provide little or no such training.

Many countries, including the United States, have no regulatory requirement for mandatory URT.[9] In safety recommendations issued in February 2002, NTSB said that FAA, in part, should "carefully review all existing and proposed guidance and training provided to pilots of transport category airplanes concerning special maneuvers intended to address unusual or emergency situations."[10] The recommendations were issued during the ongoing investigation of a Nov. 12, 2001, accident involving American Airlines Flight 587, an Airbus A300-600 that struck a residential area in Belle Harbor, New York, U.S., after the vertical stabilizer and the rudder separated from the airplane during departure from John F. Kennedy International Airport for a flight to Santo Domingo, Dominican Republic; the 260 occupants of the airplane and five people on the ground were killed. NTSB told FAA that it "learned that many pilot-training programs do not include information about the structural certification requirements for the rudder and vertical stabilizer on transport category airplanes."

During the NTSB's public hearing on the accident, Capt. Larry Rockcliff, vice president of the Airbus Training Center in Miami, Florida, U.S., testified about some of the limitations that ground-based flight simulators may have for URT.[11]

"The use of a simulator has some tremendous deficiencies or limitations for unusual, out-of-the-ordinary type flying … specifically, the forces that a pilot would experience in terms of increased weight — or g-loading, as we know of it, both vertically and laterally," Rockcliff said. "These cannot be duplicated in a simulator. … In addition, the actual fidelity— the actual information that goes into providing the simulation, the actual copy of the airplane — is in a relatively narrow band as compared to what an aggressive upset could actually cause upon a pilot."

Rockcliff said, "We discovered that the simulators in some fairly simple maneuvers were not representative of what the airplane should actually be doing." For example, he told NTSB that in one simulator, recovery from a full stall condition could be achieved by "holding the control column back and using power to fly out of it, which is absolutely incorrect."

Capt. David Carbaugh, chief pilot for flight operations safety at Boeing Commercial Airplanes, who is working with Rockcliff in coordinating the update of the *Airplane Upset Recovery Training Aid*, agrees that ground-based flight simulators currently have limitations in their effectiveness for URT.[12]

"Efforts are underway to make simulators more realistic in the post-stall regime," he said.

FAA Funds URT Research Program

Several organizations currently offer URT in airplanes, including the Flight Research Training Center (FRTC), which was established in 2002 to provide URT for 2,000 airline pilots over a five-year period. Funding for the training is provided by FAA.[13]

Based in Roswell, New Mexico, U.S., the FRTC was established by the Alliance for Flight Safety Research, a cooperative effort of the New Mexico State Highway and Transportation Department, Eastern New Mexico University–Roswell, the City of Roswell, Calspan–University of Buffalo Research Center and Veridian Corp., which was acquired by General Dynamics in August 2003 (see "Advancing the Concept of Flying an Airplane That's Not the Airplane You're Flying," page 4).

The FRTC Internet site, <flightresearchtraining.org>, says that the FAA-funded URT is available to "licensed commercial

Advancing the Concept of Flying an Airplane That's Not the Airplane You're Flying

The Cornell Aeronautical Laboratory (CAL) developed a variable-stability research aircraft in 1946 when it equipped a U.S. Navy Chance Vought F-4U Corsair fighter with an auxiliary rudder to study Dutch roll oscillations. In the 1960s, CAL combined variable-stability techniques with a new research concept: the in-flight simulator (IFS), an aircraft that has been modified to mimic the control feel and flight characteristics of another airplane.

In 1967, W.O. Breuhaus and William F. Milliken Jr. of CAL, and W.M. Kauffman of the U.S. National Aeronautics and Space Administration Ames Research Center received the Flight Safety Foundation Laura Taber Barbour Air Safety Award for their work in developing the early concepts and application of this technology.[1]

An F-4U equipped with an auxiliary rudder was one of the first variable-stability research aircraft.

One of the more striking IFS aircraft was developed in 1970, when CAL grafted a second flight deck onto the nose of a Convair 580. The result was the U.S. Air Force NC-131H total in-flight simulator (TIFS), which was used by Air Force test pilots to prepare to fly the prototype Northrop Grumman B-2 Spirit bomber.

CAL was established in the 1940s at the former Curtiss-Wright Wind Tunnel and Flight Test Department in Buffalo, New York, U.S. CAL later became the Calspan Advanced Technology Center, which was acquired by Veridian Corp. and renamed the Veridian Flight and Aerospace Research Group. In August 2003, Veridian was acquired by General Dynamics, and the Buffalo facility currently is called the Flight and Aerospace Research department of General Dynamics Advanced Information Systems.

The facility has been involved in the development of several military aircraft and civilian aircraft, including the Bombardier Global Express and the Cessna Citation X. Activities include flight testing, systems design and analysis, and pilot training.

The TIFS aircraft remains a common sight at Greater Buffalo International Airport. Other IFS aircraft currently operated by the facility are a Learjet 24D, which is used primarily for test-pilot training; a Learjet 25B, which is used for test-pilot training, research and for upset recovery training for commercial pilots at the Flight Research Training Facility in Roswell, New Mexico, U.S.; and the Air Force NF-16D VISTA (variable-stability in-flight simulator test aircraft). VISTA has been used to test fighter-aircraft designs and to evaluate the feasibility of unmanned combat aircraft.♦

— Capt. Robert L. Sumwalt III with FSF Editorial Staff

Note

1. The Laura Taber Barbour Air Safety Award, administered by Flight Safety Foundation, recognizes notable achievement in the field of aviation safety — civil or military — in method, design, invention, study or other improvement. The award was established in 1956 by the late Clifford E. Barbour and his son, Clifford E. Barbour Jr., in memory of the elder Barbour's wife, who was killed in an aircraft accident in 1945.

Front cockpit of total in-flight simulator (TIFS) airplane recently was used to test synthetic-vision systems.

pilots from regional, commuter and major airlines based in the United States. Pilots who volunteer to participate in this program must be U.S. citizens and possess a current, valid FAA-issued airman's certificate." The company offers the training to other pilots for US$6,500.

Jim Priest, director of the FRTC, said that in addition to training 2,000 airline pilots, the goals of the program are to conduct research on URT, to develop in-flight-simulation systems specifically for URT and, ultimately, to help reduce the LOC accident rate.

The FRTC began the FAA-funded URT training in July 2002, and about 200 airline pilots have received the training, Priest said.

Robert Sumwalt and Scott Buethe discuss the difference between where the airplane is pointed (i.e., attitude) and where the airplane is going (velocity vector).

The training is conducted, in part, in the center's Learjet 25B variable-stability in-flight simulator (IFS), which can be programmed to replicate the flight-handling characteristics of a generic twin-engine, swept-wing jet airplane. Several programmed upset events — including wake turbulence, flight control malfunctions and rapid cargo shifts — also can be selected by the instructor in flight and demonstrated. A single-engine, piston-powered Raytheon Beech Bonanza certified for aerobatic maneuvers also is used in the training.

Learjet Certified as Experimental Aircraft

The Learjet 25B — and a Learjet 24D used by General Dynamics primarily to train test pilots — are certified as experimental category airplanes.[14]

"Because it is an experimental aircraft, we are allowed to exceed the normal bank and pitch limits that would restrict maneuvering in a normal category airplane," Priest said. "The FAA-approved limits are 135 degrees bank, 30 degrees nose-up pitch and 20 degrees nose-down pitch. Operationally, we don't let participants exceed 90 degrees of bank. We leave the aerobatics and 'extreme' attitudes to the Bonanza."

Priest said that the airplanes' IFS programming includes a safety-monitoring system that will activate a "safety trip" if specific limits are reached. The safety trip immediately terminates the simulated upset event and allows the airplane to revert to traditional Learjet flying characteristics and controllability.

"The Learjet is certified for plus 4 g [i.e., four times standard gravitational acceleration] and minus 1 g," he said. "However, we operate so as not to exceed 2.8 g, the 'preset' limitation in the automatic safety-monitoring system. Anytime the participant tries to pull more g, the system will 'dump' the simulation (depressurize *all* hydraulic actuators), and control reverts to the safety pilot (the instructor).

"Our instructors have extensive flight-test experience and are specifically trained in IFS operations. All have intimate knowledge of the airplane, its modifications and the inner workings of the simulation system. Current and previous staff have logged over 10,000 accident-free hours of IFS operations in the two airplanes over the past 25 years."

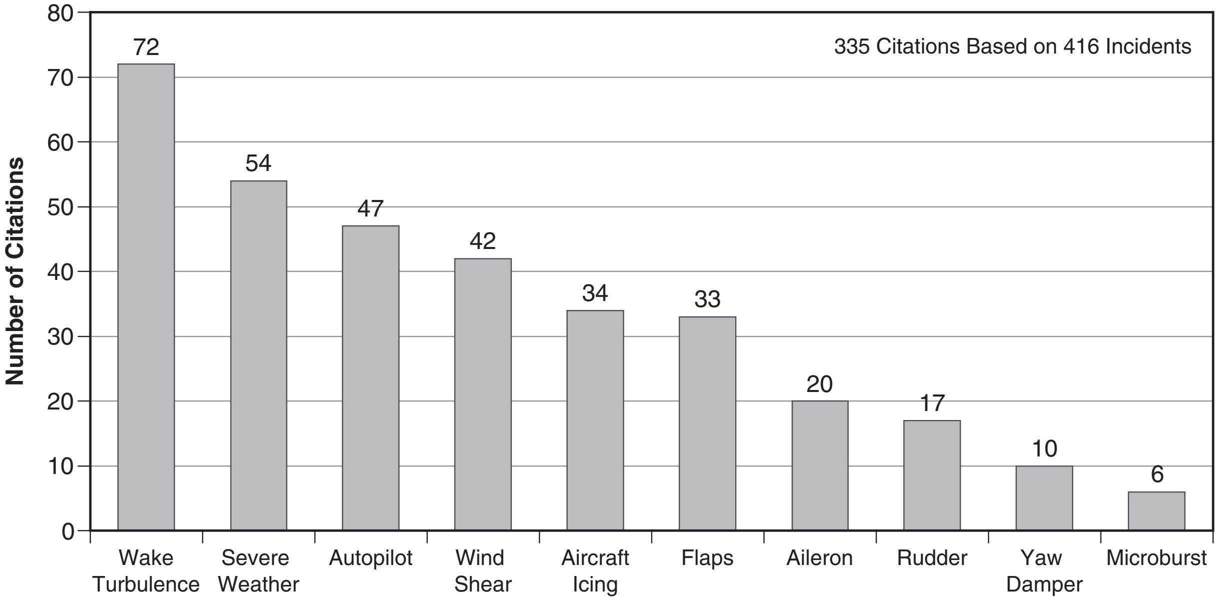
Priest said that maintenance of the Learjets is conducted on an accelerated schedule.

"For example, aileron cables are replaced at half the manufacturer's specified interval," he said. "We also have installed a loads-monitoring system consisting of strategically placed strain gauges. The data are transmitted to the manufacturer bimonthly for analysis."

Small Class Size Breeds Interaction

In August 2002, members of the Air Line Pilots Association, International (ALPA) Upset Recovery Training Project Team visited the FRTC and sampled some of the in-flight portions of the URT. As a member of the team, I received a basic overview of the four-hour classroom training syllabus, 45 minutes of instruction in the Bonanza and an hour of instruction the Learjet.

The airline that I fly for has provided URT in ground-based, full-motion flight simulators. Beyond receiving that training



Reported Causes of Multi-engine Turbojet Loss-of-control Incidents January 1996–August 2002

Notes: Data references U.S. National Aeronautics and Space Administration Aviation Safety Reporting System (ASRS) reports that have received full-form analysis and include the reporters' narratives.

Categories are not mutually exclusive, therefore, a single incident may be coded by ASRS analysts as involving more than one citation. As an example, a pilot may experience severe weather, wake turbulence and icing in the same incident.

Data are based on in-flight loss of aircraft control reports containing any reference to those categories in the reporters' narratives.

Source: U.S. National Aeronautics and Space Administration Aviation Safety Reporting System

Figure 3

and the training at the FRTC in August 2002, my experience with abnormal flight attitudes has included stalls, spins, chandelles and lazy eights as a student pilot and as a flight instructor. As an airline pilot for more than 22 years, my experience has been with "airline-style" flying, in which passenger safety and comfort, and smoothness on the controls are the objectives.

That was my experience level when I went to the FRTC in the summer of 2003 to receive full URT training.

Day one of training was devoted to four hours of classroom instruction. The instruction began at 1300, which allowed most participants to travel to Roswell that morning. Class size was limited to four students, which allowed close interaction among the instructors and students.

The classroom instruction was divided into four modules: overview, causes of upsets, aerodynamics and upset recovery. We also had the opportunity to view self-study videotapes after class.

The overview included the fundamentals of LOC and the need for URT, and laid the foundation for the remainder of the training. Instructor John Ball discussed statistics on LOC accidents in air carrier operations and in corporate airplane operations. The statistics were sobering.

Ball said that the training objective is to improve flying skills during upset events and recoveries. This objective is met by discussing upset-avoidance strategies, basic aerodynamics, airplane flight characteristics and upset-recovery techniques, and by practicing these techniques in an airplane with flying characteristics similar to those of the airplanes that we fly as airline pilots.

Upsets typically are caused by environmental factors, airplane system anomalies and/or pilot factors (Figure 3). Environmental factors include wake turbulence, severe weather and wind shear.

"The environmental category, alone, accounts for nearly two-thirds of all upsets," Ball said.

Airplane system anomalies include flight-control failures, automation problems and instrumentation malfunctions. Pilot factors include spatial disorientation and pilot-induced oscillation (PIO), also know as airplane-pilot coupling.

Ball discussed these factors and recent LOC accidents, including American Eagle Flight 4184, an ATR 72 that struck terrain in Roselawn, Indiana, U.S., on Oct. 31, 1994, after accumulating a buildup of ice aft of the wing-deicing boots. The resulting uneven airflow across the wings led to an aileron being aerodynamically forced and held up — a phenomenon known as "aileron snatch" — and subsequent loss of control.[15]

Training Introduced Concept of Velocity Vector

The discussion of aerodynamics by engineering pilot Scott Buethe included the basics, as well as more advanced material. He discussed *velocity vector*, a term used to represent an airplane's speed and direction.

"In simplistic terms, velocity vector represents 'where the airplane is going' and 'how quickly it will get there,'" he said. "Velocity vector is really just a snapshot of flight path at any given time. As we change velocity vector, flight path is altered in that direction."

Buethe used a model airplane with a retractable pointer affixed to its belly to demonstrate the concept. He swiveled the pointer to indicate the airplane's flight path and lengthened or shortened the pointer to indicate its velocity. He also bent the pointer to indicate the effect on velocity vector of "loading" and "unloading" the airplane.

He reminded us that loading the airplane means increasing the load factor (also called "g" or gravitational acceleration) by aft movement of the elevator control, whereas unloading the airplane means decreasing the load factor by forward movement of the elevator control.

Buethe also discussed dihedral effect, which causes an airplane to roll when a slide slip is induced.

"If the airplane is rolling due to a rudder hard-over, the dihedral effect can be reduced by unloading the airplane," he said. "Unloading the airplane does several things that work to our advantage: It reduces angle-of-attack (alpha), and it increases roll response, because the ailerons are more effective at lower alpha."

Conversely, if the airplane is rolling and aileron control is not effective in slowing or stopping the roll, loading the airplane will increase the dihedral effect, which allows the rudder to be more effective, Buethe said.

Success May Depend on Communication

Ball continued our instruction in upset recovery by noting that because airplane upsets occur so infrequently, there is often a substantial "startle factor" that can slow or inhibit the crew's response. Effective crew coordination during an upset can be a key factor in successful recovery.

"Just announcing what the problem is will give your flying partner a heads-up on what you are facing and get him or her thinking in the right direction," Ball said. "He may be able to help you by holding control forces, splitting throttles [to apply asymmetric power] or even suggesting things that may help."

He acknowledged, however, that the stress of the situation and the limited recovery time can saturate cognitive resources, which may make effective communication more difficult.

The crew must evaluate the airplane situation. This should include an instrument cross-check for erroneous information (see "New Airline Pilots May Not Receive Sufficient Training to Cope With Airplane Upsets," page 19).

"Autopilots and autothrottles should be disconnected at the first sign of a problem," Ball said.

Before disconnecting the autopilot, however, the pilot should check trim indicators and yoke position to determine whether the autopilot is correcting a roll or pitch moment induced by airframe icing, asymmetric power or other factors. If the autopilot is near its performance limits, the airplane might react abruptly when the autopilot is disconnected. A firm grip on the flight controls always is advisable during autopilot disconnection.

Ball stressed the importance of properly assessing the airplane's attitude. If you have adequate outside visual cues, use those cues. If outside visual cues are unavailable, however, refer to the attitude direction indicator (ADI) and compare the position of the miniature airplane display to any of the following ADI displays: the horizon line; sky/ground colors; sky pointer (typically an arrow that shows which way is up); pitch ladder (the number-and-line markings that denote pitch attitude); and the zenith and nadir indications, which are the 90-degree nose-up indication and the 90-degree nose-down indication, respectively. Unlike older mechanical ADIs, electronic ADIs generally display some indication of the horizon, regardless of airplane's actual pitch attitude, he said.

Although referring to the sky pointer has been a long-suggested technique, Ball said that some pilots have difficulty with this technique and tend to roll the airplane the wrong way.

"It is not quite as obvious at it might be," he said. "A previous URT student suggested that to avoid this confusion, take the top of the yoke and turn toward the sky pointer, or simply turn toward the blue."

Concurrent with determining the airplane's attitude, successful upset recovery depends on proper assessment of velocity vector. The FRTC training materials recommended the following actions:

- Check airspeed;
- Check angle-of-attack (AOA) with:

  - AOA indicator, if available;
  - Loading (“g”) and airspeed combination;
  - Stick shaker (stall warning); and/or,
  - Control-column force; and,
- Check side slip with:
  - The “ball” in the slip/skid indicator (or equivalent indicator);
  - Side force felt in the “seat of pants”; and/or,
  - Asymmetric thrust.

No Time to Be Smooth

URT cannot have a “one-size-fits-all” methodology with standard procedures suitable for all pilots in all upset situations. Nevertheless, the FRTC offers a technique that works for many upset situations:

- Unload the airplane with forward movement of the control column;
- Roll as required to wings-level; and,
- Pull the nose to the horizon — or, if altitude is critical, above the horizon to stop a descent.

Ball said that pilots must be prepared to move the control column to a stop if necessary to recover from an upset.

> ***“We generally are able to train pilots to make the necessary inputs. They have to make a switch between ‘normal line flying inputs intended to not spill the coffee’ and ‘upset recovery inputs needed to save lives.’”***

“Airline pilots tend to be nice and smooth on the controls and use a small percentage of control authority available,” Ball said. “In an upset situation, you must put it right to the stop, if needed. The fact that you have a lot of control wheel input makes it seem like you’ve got it *all* in. Quite often, when we first go up and give people an upset, they’ll swear they hit the stop, when in reality, they had considerably more to go.”

Priest agreed with Ball’s observation.

“At the beginning of training, we see a general tendency to undercontrol — or more broadly, under-react — and a general unwillingness to make the necessary inputs,” he said. “We generally are able to train pilots to make the necessary inputs. They have to make a switch between ‘normal line flying inputs intended to not spill the coffee’ and ‘upset recovery inputs needed to save lives.’”

Priest said that the FRTC emphasizes use of a “measured response,” meaning to make a control input and see if it is achieving the desired response. If it is not, then increase the control input. If it is too much, then reduce control input by an appropriate amount.

“This does not mean small control adjustments,” he said. “It means: Use all necessary control, up to full input. It also means: Don’t bang the control column against the stop if not absolutely necessary. We need to always remain aware of the structural limitations of the airplane.”

Besides being startled by an upset, pilots likely will experience distracting factors such as unusual g forces, stress, warning lights and audible warnings such as a stall warning or overspeed warning, improperly fastened seat restraints and flying objects and debris in the cockpit.

“We want you to see these in training, so they won’t be so unusual should you encounter them in regular flights,” Ball said.

Pilots also might find that when upset, an otherwise normally functioning airplane will have unexpectedly poor handling qualities. Pilots who have flown high-performance airplanes find that large transport category airplanes are not as agile and will not respond as quickly.

Every Control Has a Backup

Buethe completed the classroom instruction with a discussion of alternate control methods.

“For all of our various controls, we are going to have a backup,” he said.

For example, a pilot struggling to control a nose-up pitch condition may find success by banking the airplane, using stabilizer trim or using engine thrust strategically. With underwing-mounted engines, a thrust decrease will pitch the nose down; with tail-mounted engines, a thrust increase will pitch the nose down.

The effects that spoilers, landing gear and flaps have on pitch attitude vary among airplanes. On some airplanes, a specific amount of flap extension will pitch the nose in one direction, but greater amounts of flap extension will pitch the nose in the opposite direction. Furthermore, Ball said that gear extension might do the opposite of what the pilot expects. The implication is to be very familiar with the characteristics of your airplane.

“When extending gear and/or flaps, be very cautious, judicious and deliberate,” Buethe said.

A flight-test engineer uses a computer to control complex research simulations conducted in the Learjet IRS; for URT, however, the left-seat safety pilot uses a handheld device to control the simulations. (Photo: General Dynamics)

Differential thrust can be an effective backup for roll control.

"An airplane rudder is designed to counteract an asymmetry due to an engine failure — so it follows that differential thrust can be used to counter a rudder hard-over," Buethe said.

He warned, however, that if thrust is used improperly, the pilot will add immeasurably to the problem and decrease the chance of successful recovery.

Lessons From the Learjet

I will admit a degree of trepidation as the time arrived for flight training. My concerns — in approximate order of primacy — were to have a safe flight, avoid becoming airsick and, finally, not make a fool of myself. The one that I was the least confident about was avoiding airsickness.

To try to beat the summer heat of the New Mexico desert, two training-slot times were established. One group would brief and fly from 0600 to 1000; the other would brief and fly from 0800 to 1200. I drew the later time slot. On the first day of flight training, my training partner would fly the Bonanza while I flew the Learjet.

Buethe was my instructor. We took about two hours to brief the upcoming flight. The objectives of the first flight would be to demonstrate airplane handling characteristics and upset recoveries, and to practice recoveries from selected upset scenarios. Buethe provided a detailed description of how the flight would be conducted.

Buethe occupied the left seat, which has conventional controls and flight characteristics. The FRTC has FAA authorization to allow pilots, such as myself, who are not Learjet-qualified to occupy the right seat for IFS demonstrations conducted within specific parameters and guidelines.

The right-seat control column and rudder pedals are fly-by-wire controls; they are not connected directly to their respective control surfaces. Any control input made by the right-seat pilot is processed by multiple high-speed digital computers into electrical "signals" that are sent to hydraulic and/or electric control-surface actuators.

The IFS computers also are used to initiate in-flight upsets, in the same way that a ground-based full-motion simulator uses digital computer models to calculate the response of the simulated airplane. For example, when Buethe selects the computer's rudder hard-over mode, the airplane reacts as if the rudder on a large swept-wing transport category airplane had traveled to full deflection. The right-seat pilot then attempts recovery.

After the briefing, we conducted maneuvers in a fixed-base ground simulator.

"This is sort of a warm-up before flying the airplane," Buethe told me. "It ensures that each participant understands the underlying concepts before the flight training begins."

I found that the warm-up provided an excellent opportunity to interact with the instructor and to ask questions as they arose. As we proceeded through the flight scenarios, Buethe discussed some common errors and tendencies that other pilots have demonstrated. He reminded me, for example, that line pilots have a tendency to not apply and maintain full control authority when necessary.

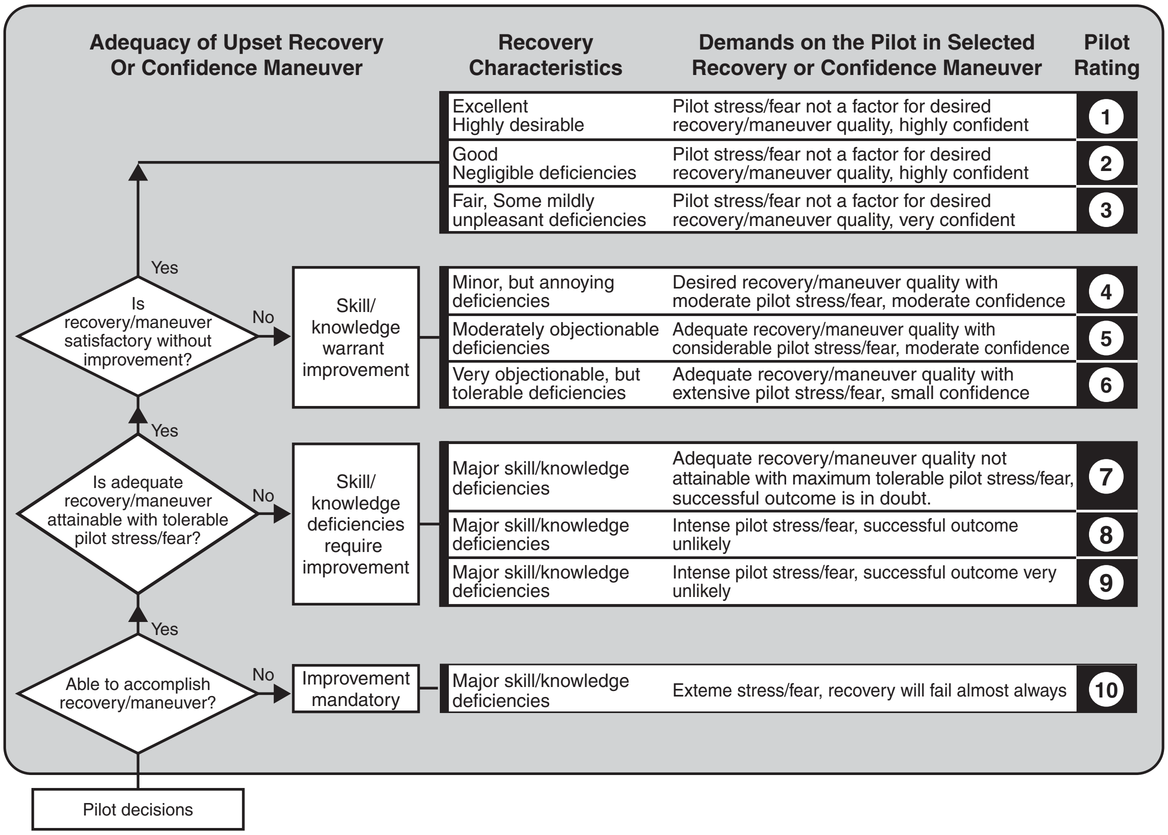
"For an aileron hard-over, there is a real tendency to not use full control input and hold it there," he said.

He then showed me the FRTC's "Upset Recovery Quality Rating Scale" (Figure 4, page 10) and told me that after specific upset-recovery maneuvers, I would refer to the rating scale and subjectively rate my level of performance, confidence and stress. If I then elected to try the maneuver again, we could quantify any improvements.

We proceeded to the airplane, and Buethe showed me the walk-around inspection procedure. The morning cloud cover had almost vanished, and we were fortunate to have relatively cool temperatures — about 30 degrees Celsius (86 degrees Fahrenheit) on the ground. (Two weeks earlier, daytime surface temperatures had peaked at about 43 degrees Celsius [110 degrees Fahrenheit]).

Priest accompanied us on the first flight to observe from the jump seat. Buethe conducted all the checklists, started the engines, handled communication with air traffic control (ATC), taxied the Learjet to the runway and flew the takeoff. After retracting the landing gear and flaps, he transferred airplane control to me. I remarked that the airplane has a very nice feel, similar to other transport category airplanes that I have flown.

Upset Recovery Quality Rating Scale



Recovery Characteristics	Demands on the Pilot in Selected Recovery or Confidence Maneuver	Pilot Rating
Excellent Highly desirable	Pilot stress/fear not a factor for desired recovery/maneuver quality, highly confident	1
Good Negligible deficiencies	Pilot stress/fear not a factor for desired recovery/maneuver quality, highly confident	2
Fair, Some mildly unpleasant deficiencies	Pilot stress/fear not a factor for desired recovery/maneuver quality, very confident	3
Minor, but annoying deficiencies	Desired recovery/maneuver quality with moderate pilot stress/fear, moderate confidence	4
Moderately objectionable deficiencies	Adequate recovery/maneuver quality with considerable pilot stress/fear, moderate confidence	5
Very objectionable, but tolerable deficiencies	Adequate recovery/maneuver quality with extensive pilot stress/fear, small confidence	6
Major skill/knowledge deficiencies	Adequate recovery/maneuver quality not attainable with maximum tolerable pilot stress/fear, successful outcome is in doubt.	7
Major skill/knowledge deficiencies	Intense pilot stress/fear, successful outcome unlikely	8
Major skill/knowledge deficiencies	Intense pilot stress/fear, successful outcome very unlikely	9
Major skill/knowledge deficiencies	Exteme stress/fear, recovery will fail almost always	10

Source: General Dynamics Flight Research Training Center

Figure 4

We operated the airplane in an altitude block between 12,000 feet and 17,500 feet, which at the lowest point was about 8,000 feet above the desert.

We began by conducting some “confidence maneuvers” to help me get a feel for the airplane and the g forces that I, like many airline pilots, had not experienced recently.

“The idea is to calibrate your body so that you know what a 2.5 g pull and a 0.5 g push feel like, since these are the values you will be shooting for in some of these recoveries,” Buethe said.

I noticed that when I first attempted to pull 2.5 g — the positive limit load factor for certification of most transport category airplanes — I tended to not pull hard enough on the control column and did not pull 2.5 g.

To get the feel for negative g loading, we pulled the airplane into a nose-high attitude. Buethe then said, “Recover.” I attempted to reach 0.5 g but tended not to achieve enough of a push. I proved what had been discussed in the classroom — that, after years of striving to fly smoothly, many airline pilots initially tend to undercontrol.

Buethe recommended that in recovering from a nose-high attitude, instead of only pushing the nose over, I also should roll the airplane into a bank to divert the lift vector and help the nose drop. How much bank? The training aid says that the angle of bank normally should not exceed 60 degrees.

Buethe told me that a 30-degree bank will reduce the vertical lift component only 30 percent, whereas 60 degrees of bank will reduce the vertical lift component by half. He said that although extreme caution must be exercised when steeply banking a large swept-wing transport category airplane, if no other method is effective in lowering the nose, a pilot should keep in mind that a 90-degree bank angle will reduce the vertical lift component to zero.

In subsequent maneuvers, I found that when the nose is pointed up and all other means, such as trim changes and thrust changes, are ineffective, rolling the airplane is an excellent method to get the nose down.

For the next maneuvers, the flexibility of the Learjet IFS came into play. Buethe simulated moving the center of gravity (CG) to an extreme nose-heavy position, and he encouraged me to make elevator-control inputs. I found that the elevator-control forces felt heavier but that the airplane felt very stable. When changing pitch attitude, for example, the nose tended to stop very quickly where I placed it.

Buethe then simulated an extreme aft-CG condition. Clearly, the physical control forces required to manipulate pitch were lower, but when I was told to abruptly change pitch attitude to a specific value, I noticed an unmistakable tendency to overshoot. Unlike the forward-CG condition, in the aft-CG condition the airplane did not tend to resist pitch changes.

"It takes less physical effort to control the airplane in this situation, but higher mental workload," Buethe said.

Next on the agenda was simulating a rapid cargo shift, causing the airplane's nose to pitch up substantially. Per my classroom training, I called out, "I have a pitch control problem," to inform the other pilot of the predicament.

When it became apparent that trim and secondary controls such as thrust would not arrest the pitch-up, Buethe said, "Roll to divert that lift vector."

Dealing With Dutch Roll

Buethe then programmed the airplane to go into Dutch roll oscillations, which begin in swept-wing airplanes when a yaw displacement, typically caused by turbulence, induces a side slip.

For demonstration purposes — not to practice alternative recovery methods — we experimented with three ways of dealing with the situation: using ailerons only, using rudder only and using a combination of aileron and rudder. Quickly apparent was the reason why manufacturers of swept-wing transport category airplanes recommend recovering from Dutch rolls by using ailerons alone (and why they install yaw dampers to reduce Dutch roll tendency). When I tried the rudder-only method, I quickly became out of phase with the oscillations and exacerbated the Dutch roll oscillations.

"We must watch the rate at which the nose moves and not the actual nose position," Buethe said. "The greater the yaw rate, the more we must oppose it."

He noted that the yaw rate is highest as the nose comes through the "zero-side-slip" (or middle) position.

Next was a demonstration of pitch-axis PIO. In its report on the McDonnell Douglas MD-11 accident at Newark, New Jersey, U.S., NTSB said, "PIO in the pitch axis can occur when pilots make large, rapid control inputs in an attempt to quickly achieve desired pitch-attitude changes. The airplane reacts to each large pitch-control input, but by the time the pilot recognizes this and removes the input, it is too late to avoid an overshoot of the pilot's pitch target. This, in turn, signals the pilot to reverse and enlarge the control inputs, and a PIO with increasing divergence may result."[16]

The PIO demonstration was effective in showing how quickly a pilot can get out of phase with the airplane's movements. The FRTC teaches that recovery from PIO can be achieved by aborting the task (e.g., going around), freezing (holding steady) or releasing the controls, and opposing the rate of movement rather than the angle of movement.

Robert Sumwalt "warms up" in a fixed-based simulator under the direction of Scott Buethe before flying the Learjet.

Having participated as an ALPA representative in the NTSB investigation of the USAir Flight 427 accident — a Boeing 737 that struck terrain near Pittsburgh, Pennsylvania, U.S., in September 1994 — I was particularly interested in the next demonstration: a rudder hard-over upset.[17,18]

"Oh, I have a flight control problem," I announced and began reacting to the simulated rudder hard-over. Quickly, the situation worsened. Safety trip. Buethe recovered. He then handed me the Upset Recovery Quality Rating Scale and asked me to rate my performance. My personal rating was one that I was not pleased with.

"Let's do it again," he suggested. "This time, go all the way to the full stop on the aileron, if needed, and then consider calling for differential thrust to counter the asymmetry."

I conducted the recovery as he suggested. Much better. Using the rating scale, I calculated that my performance improved 40 percent. I was confident that with more practice, my performance and confidence would have improved even more, and the stress would have lessened. Nevertheless, because of my concern about airsickness, we decided to leave well enough alone and not continue to practice the maneuver.

Real Upsets Don't Provide a Second Chance

In retrospect, two aspects of the rudder hard-over recovery training impressed me:

- Although I had participated in numerous real-time simulations as part of the USAir Flight 427 investigation, including experiencing the calculated g forces in the U.S. National Aeronautics and Space Administration (NASA) Vertical Motion Simulator, and had listened to the cockpit voice recorder (CVR) recording several times, I was amazed during my training in the Learjet at how quickly this scenario unfolded and how little time was available to apply the correct recovery procedure. There is quite an "adrenalin rush" when you are pointed toward the ground and the airplane does not seem to be responding to your control inputs.
- In the training environment, I was not happy with my performance the first time, so we repeated the maneuver. When a rudder hard-over occurs for real in line operations, the pilot will not have the luxury of repeating the maneuver until he or she is satisfied with their performance. It happens fast, and the recovery must be right. There won't be second chances.

The Learjet flight also included a demonstration of an aileron hard-over and the differences in the recovery procedure. With a rudder hard-over, unloading the airplane helps increase controllability. Conversely, when faced with an aileron hard-over, loading the airplane by pulling back on the control column actually can increase the rudder's effectiveness in countering the roll. This is because the dihedral effect is increased when the airplane is loaded. Also, for a rudder hard-over, a speed increase is helpful because it increases the effectiveness of the ailerons in countering the roll induced by the rudder. For an aileron hard-over, however, a speed increase can be counterproductive, because as the airflow over the wings increases, the effectiveness of the ailerons increases. (You want to decrease the effect of the ailerons, not increase it.)

Next, Buethe programmed a wake turbulence encounter. In line flying, I had not experienced any of the previous events that we had simulated in the Learjet, but I had encountered wake turbulence and can attest to the fidelity of the wake encounter simulation. It felt quite real, just as if we had flown into the wake of a heavy transport category airplane. I know that as the airplane exits the wake, the pilot must be prepared to aggressively remove roll inputs, or he will roll the airplane the opposite way.

We performed two wake turbulence upset recoveries. My instructor was satisfied with my performance.

"Good," Buethe said. "You used a 'measured input,' which is what we want to see."

Using Throttles for Flight Control

To complete the training session, he told me to turn to a heading of 360 degrees and descend to 10,000 feet. When I turned the control wheel to comply, there was no response … absolutely none. Buethe had set me up to find alternate ways to control the airplane.

The situation was similar to the one faced by the crew of United Airlines Flight 232 after an uncontained engine failure caused a loss of all hydraulic pressure for the flight controls in their DC-10. The crew used differential thrust to fly the crippled airplane for an emergency landing at Sioux City, Iowa, U.S.[19]

Unlike the system failure that confronted the DC-10 crew, our simulated flight-control failure allowed use of stabilizer trim for pitch control. I delegated pitch control to Buethe so that I could focus on steering the airplane with only differential thrust.

"Of course, in this situation, you would want to give yourself a long final approach to get set up," Buethe said.

I was amazed at the airplane's responsiveness to differential-thrust applications. The turn to final approach went better than I had anticipated, but as we got lower, we encountered strong thermals from desert heating. The thermals and a slight crosswind helped nudge us off the extended runway centerline, and a landing on the runway was not possible — at least on this attempt. We could have gone around and tried to sort it out better on the next approach, but because this was strictly a demonstration, I transferred control to Buethe, who landed the airplane with the flight controls fully operating.

Overall, my Learjet flight training comprised about an hour.

Lessons From the Bonanza

The next day, I received flight training in the Bonanza. The objectives were demonstration and practice of flight path management, energy management and basic recovery techniques. My instructor was Greg Clausen, a furloughed airline pilot and former U.S. Air Force F-15 pilot.

We took a good bit of time briefing the flight. I expressed my desire to avoid airsickness, and we agreed that we would delete from the syllabus a few of the initial maneuvers, including recoveries from stalls and accelerated stalls, which I had done when I flew the Bonanza during my visit to the facility with the

The sensation of seeing the ground fill the windshield cannot be replicated in a ground-based simulator.

ALPA team in August 2002. I told Clausen that I just wanted to practice some of the more advanced maneuvers.

We climbed the airplane to 10,000 feet and began the maneuvers with lazy eights, which consist of continuous climbing turns and diving turns usually with relatively shallow bank angles.

"Use as much bank as you're comfortable with, up to 90 degrees," Clausen said.

After conducting a series of lazy eights, I proudly announced that I used about 90 degrees of bank. Clausen politely pointed out that I actually had used about 60 degrees of bank.

Similar to the previous day's training in the Learjet, we raised and lowered the Bonanza's nose to help me "calibrate" my subjective estimates of g forces. Like the previous day, I had a little difficulty forcing myself to sufficiently load and unload the airplane.

Next on the syllabus was aileron rolls. Clausen told me that the goal is not to teach pilots how to perform rolls but to teach pilots how to recover from a nose-down and steeply banked attitude.

"The roll is just an easy way to get us to that point," he said.

Apparently sensitive to my concern about becoming airsick, Clausen asked me several times how I felt. I told him that I was having fun but that I did not want to push myself and end up sick. He said that with the exception of a loop, we had done everything that was scheduled for the flight.

In retrospect, I wish I had done the loop. Nevertheless, remembering the sweat dripping from my brow at the time, I suspect that the decision to terminate the flight when we did was a wise one.

Impressions of the Training

The FRTC training was a tremendous learning experience. I believe, however, that although it gave me more exposure to the dynamics of airplane upsets and the techniques for upset recovery, it did not train me fully in these topics. Recurrent URT is vital.

My classmates agreed with me that recurrent URT is vital. We also agreed that training to prevent upsets is just as important as URT (see "Preventing the Upset from Occurring: The Essential First Step," page 14).

The FRTC training was a confidence-booster, but it also made me realize that airplane upsets can occur extremely quickly and that very little time likely will be available for recovery.

The classroom instruction was valuable in increasing my knowledge about upsets and recovery techniques. The FRTC flight training was very effective in reinforcing lessons learned in the classroom.

In addition to enabling the trainee to actually feel g forces and control loading, flight training reveals the sensations of seeing the ground filling the airplane's windshield or a horizon cocked at a 135-degree angle.

With this realism, however, comes a potential downside. Years ago, airlines, corporate flight departments and training organizations changed from using airplanes for training to using ground-based simulators for training because of the financial costs and the risks associated with in-flight training. Many accidents have occurred during in-flight training.

A minor disadvantage of airplane training is one that I certainly felt — apprehension and motion sickness. Although I never actually became nauseated, the thought of being sick was constantly in my mind. Consequently, each of my flight sessions (during both my August 2002 visit and this visit) were shortened. As a result, the level of my learning experience was decreased. I am certain, however, that with increased exposure to the abnormal sensations, my tolerance would increase and my apprehension would wane.

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Preventing the Upset From Occurring: The Essential First Step

After completing upset recovery training (URT) at the Flight Research Training Center, my classmates and I discussed what we had learned and what further might be done to help prevent loss of control (LOC) accidents.

Among the ideas we discussed was that industry URT training also should include what can be done to *prevent* upsets from occurring.

"When potential upset conditions are discovered early, it may be possible to prevent the condition from becoming an upset," said Capt. Ron Thomas, supervisor of flight standards and training for US Airways.

Capt. Terry Tubb, director of flight operations for a major U.S.-based carrier, agreed, stating his belief that training pilots to recognize potential upset conditions is a "missing element" from industry efforts to reduce LOC accidents.

"Both the airline industry and URT vendors should be training on recognition and recovery from instrument errors, particularly pitot-static errors," he said. "The industry has seen numerous hull losses due to instrument errors leading to an upset."

An example was the December 1974 accident involving a Northwest Airlines Boeing 727 during departure from New York, New York, U.S., for a ferry flight. The flight crew had not selected the pitot-heat system, and the pitot heads became blocked with ice during the climb. The flight crew reacted to the resulting erroneous airspeed indications by increasing the airplane's pitch attitude. The airplane stalled at 24,800 feet and spiraled to the ground. The three flight crewmembers were killed, and the airplane was destroyed. The U.S. National Transportation Safety Board (NTSB) said that the probable cause of the accident was "the loss of control of the aircraft because the flight crew failed to recognize and correct the aircraft's high angle-of-attack, low-speed stall and its descending spiral."[1]

Tubb said, "Pilots should be taught techniques to stabilize the attitude and fuel flow [i.e., set normal cruise fuel flow] while attempting to troubleshoot instrument errors, especially pitot-static errors which can affect multiple instruments during an event. Techniques involving HSI [horizontal situation indicator] errors should be discussed [along with appropriate training]. The objective would be to recognize a situation that could result in an upset if not correctly identified and resolved."

We discussed several other airplane upsets that might have been prevented by adequate monitoring and cross-checking. One accident, in February 1985, involved loss of power from the no. 4 engine on a China Airlines Boeing 747 that was en route at 41,000 feet from Taipei, Taiwan, China, to Los Angeles, California, U.S. The autopilot remained engaged while the crew attempted to restore engine power. As airspeed decreased, asymmetric forces on the airplane caused the autopilot to automatically disconnect. The airplane rolled right, pitched nose-down and descended. Two of the 274 occupants — a passenger and a flight attendant — received serious injuries, and the airplane was damaged substantially during the upset. The flight crew regained control of the airplane at 9,500 feet and diverted to San Francisco, California. NTSB said that the probable cause of the accident was "the captain's preoccupation with an in-flight malfunction and his failure to monitor properly the airplane's flight instruments, which resulted in his losing control of the airplane. Contributing to the accident was the captain's over-reliance on the autopilot after the loss of thrust on the no. 4 engine."[2]

A similar upset occurred in April 1993 when a Continental Express crew lost control of their Embraer Brasilia while climbing through 17,000 feet. NTSB said that the captain had selected an improper autopilot mode — the pitch-hold mode, rather than the climb mode. As airspeed decreased, the captain was engaged in conversation with the flight attendant and the first officer was making entries in the aircraft logbook and eating a meal. The airplane stalled at a higher-than-normal airspeed because the wings had become contaminated with ice. The airplane was substantially damaged during the uncontrolled descent. The crew regained control at about 5,000 feet and diverted to Pine Bluff, Arkansas, U.S., where the airplane overran the runway on landing. Twelve passengers and the flight attendant received minor injuries; the other 17 occupants received no injuries. NTSB said that the probable causes of the accident were "the captain's failure to maintain professional cockpit discipline, his consequent inattention to flight instruments and ice accretion, and his selection of an improper autoflight vertical mode, all of which led to an aerodynamic stall, loss of control and a forced landing."[3]

Thomas said, "At least one pilot must always monitor the aircraft. Because it is difficult to stay focused on monitoring during low-workload conditions, it may be beneficial for pilots to alternate this monitoring responsibility during cruise."[4]♦

— Capt. Robert L. Sumwalt III

Notes

1. U.S. National Transportation Safety Board (NTSB). Aircraft Accident Report: *Northwest Airlines, Inc., Boeing 727-251, N274US, Near Thiells, New York, December 1, 1974*.
2. NTSB. Aircraft Accident Report: *China Airlines Boeing 747-SP, N4522V, 300 Nautical Miles Northwest of San Francisco, California, February 19, 1985*.
3. NTSB. Aircraft Accident/Incident Summary Report: *In-flight Loss of Control Leading to Forced Landing and Runway Overrun, Continental Express, Inc., N24706, Embraer EMB-120RT, Pine Bluff, Arkansas, April 29, 1993*. See also: Lawton, Russell. "Airframe Icing and Captain's Improper Use of Autoflight System Result in Stall and Loss of Control of Commuter Airplane." *Accident Prevention* Volume 51 (November 1994).
4. For more information, see: Sumwalt, Robert L. "Enhancing Flight Crew Monitoring Skills Can Increase Flight Safety." *Flight Safety Digest* Volume 18 (March 1999).

Nevertheless, as mentioned above, ground-based simulators have limitations also (see "Pro and Cons of Using Ground-based Simulators for Upset Recovery Training.")

Thus, there are advantages and disadvantages to URT in ground-based simulators and in in-flight simulators. Having

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Pros and Cons of Using Ground-based Simulators for Upset Recovery Training

Aviation Safety Training (AST) has administered upset recovery training (URT) in Beech T-34 airplanes to more than 2,200 pilots. The company, which is based at David Wayne Hooks Memorial Airport near Houston, Texas, U.S., offers initial URT and recurrent URT, and recently added optional ground-simulator training to the recurrent URT curriculum.

Don Wylie, AST's president and chief pilot, said that he has seen students recover from situations in the simulator that would have been too hazardous to practice in flight.[1]

"You can do things in the simulator that you cannot physically do in the aircraft," he said.

[At press time, the FSF editorial staff learned that Wylie and a student were killed Nov. 19, 2003, during a training flight. A preliminary report by the U.S. National Transportation Safety Board (NTSB) said that the airplane "crashed while performing maneuvers."]

The use of ground-based simulators for URT was described as a "two-sided coin" by Edward Cook, Ph.D., manager of the U.S. Federal Aviation Administration Flight Standards National Simulator Program.[2] On one side of the coin are the limitations and pitfalls.

"A simulator is not an aircraft; it is a computer," he said. "It will only operate according to the way that it is programmed. When going outside the normal flight envelope, there may be insufficient data in the program to provide an accurate model."

Wylie and Cook agree that a pilot could get the false impression that an upset-recovery technique performed successfully in a simulator would be effective in an airplane when, in reality, the technique might overstress and destroy the airplane.

"Just because the simulator will recover, does not necessarily mean that the airplane can do the same," Cook said. "You cannot get a simulator to perform like an airplane in certain flight regimes."

On the other side of the coin, ground simulators are valuable tools for training and testing pilots. Wylie said that conducting maneuvers in a simulator helps to develop "muscle memory" that later will be called upon when training in an airplane.

Cook said that in developing URT programs using ground simulators, the advantages as well as the limitations should be considered.

"Just because ground-based simulators have limitations, we should not 'throw the baby out with the bath water,'" he said. "Simulators are useful trainers, provided you understand and appreciate their limitations."

Some loss-of-control (LOC) accidents have involved situations in which the airplane did not depart from the normal operating envelope; therefore, demonstrating recovery from those types of events could be performed quite well in simulators, he said.

"Simulators should be used as a demonstration tool for URT and not as a task trainer," Cook said. "Simulators should be used to demonstrate to flight crewmembers what 'upside down' looks like out the cockpit window and on the instruments; to demonstrate how you would determine what direction of roll would bring the airplane to the correct attitude in the shortest amount of time; to demonstrate that 'unloading' the airplane (reducing g loading) is the surest way to gain airflow over critical control surfaces."

SimCom, a division of Pan Am International Flight Academy, also uses ground simulators and airplanes for URT. Tracy Brannon, managing director of SimCom, said that their URT program includes several hours of ground briefings, training in a ground-based simulator with a 220-degree visual display and in-flight training in a Super Decathlon, a reciprocating-engine, aerobatic airplane.[3]

"Beginning in the simulator allows the student to become familiar with control inputs," Brannon said. "The high-fidelity visual system provides an opportunity for the students to see the different attitudes that they will later see in the aircraft."

SimCom is primarily a simulator-training organization, but "we realized that our URT program would have to involve using an airplane," said Brannon.♦

— Capt. Robert L. Sumwalt III

Notes

1. Wylie, Don. Personal correspondence with Sumwalt, Robert L. Columbia, South Carolina, U.S. 4 August 2003. Columbia, South Carolina, U.S.
2. Cook, Edward. Personal correspondence with Sumwalt, Robert L. Columbia, South Carolina, U.S. 4 August 2003. Columbia, South Carolina, U.S.
3. Brannon, Tracy. Personal correspondence with Sumwalt, Robert L. Columbia, South Carolina, U.S. 5 August 2003. Columbia, South Carolina, U.S.

participated in both types of URT training, I believe that an effective method would be to have pilots undergo in-flight training initially upon employment and thereafter at periodic intervals — perhaps every three years or every five years. Between these periods, annual training in a ground-based simulator could prove effective in reinforcing awareness of airplane upsets and recovery techniques. Simulators could be equipped with data-gathering equipment, similar to the quick-access recorders used in flight operational quality assurance (FOQA) programs, to enable the identification of inappropriate control inputs that could cause structural damage or failure to an actual airplane.

Reducing LOC accidents, however, will require more than initial training and recurrent training of professional pilots. By the time a pilot reaches the flight deck of a corporate jet or an airliner, that pilot already should have demonstrated some degree of proficiency in recovering from airplane upsets. This would be similar to the FAA requirement that all certified flight instructors, as part of their qualification for that rating, must have a logbook endorsement showing that they have received instruction and demonstrated proficiency in spin recoveries. I also believe that it would not be unreasonable to require that a pilot seeking employment in a corporate or airline flight department should be required to demonstrate some level of proficiency in recovering from airplane upsets.

Having completed the training at the FRTC, I am certain that courses like this help pilots deal with the unexpected and, thus, improve aviation safety.♦

Notes

1. Boeing Commercial Airplanes. *Statistical Summary of Commercial Jet Airplane Accidents, Worldwide Operations, 1959–2002*. May 2003. The data show that of 6,772 fatalities in 1993 through 2002, 2,131 fatalities occurred in accidents involving loss of control in flight. The data include accidents involving Western-built commercial jet airplanes with maximum gross weights of more than 60,000 pounds/27,000 kilograms; the data do not include accidents involving airplanes manufactured in the Commonwealth of Independent States and commercial airplanes in military service. (See “More Than Half of Large Commercial Jet Accidents in 2002 Occurred During Approach and Landing,” page 33.)

2. Matthews, Bob; U.S. Federal Aviation Administration (FAA) Office of Accident Investigation; U.S. Commercial Aviation Safety Team (CAST) Data Analysis and Implementation Team. Personal correspondence with Sumwalt, Robert. Columbia, South Carolina, U.S. 31 July 2003. Columbia, South Carolina, U.S.

3. The text portion of the *Airplane Upset Recovery Training Aid* is available on the FAA Internet site at <www2.faa.gov/AVR/afs/afs200/afs210/index.cfm>.

4. Carbaugh, David; chief pilot for flight operations safety, Boeing Commercial Airplanes. Personal correspondence with Sumwalt, Robert. Columbia, South Carolina, U.S. 8 July 2003. Columbia, South Carolina. U.S. Carbaugh participated in the development of the *Airplane Upset Recovery Training Aid* and, with Capt. Larry Rockcliff, vice president of the Airbus Training Center in Miami, Florida, U.S., is coordinating the efforts to update the training aid. Carbaugh said that the update will include lessons learned over the past three years, including use of rudder in an upset situation, and material to improve pilots’ understanding of airplane-handling characteristics.

5. The Safer Skies general aviation initiative is being conducted by the General Aviation Joint Steering Committee, and the commercial aviation initiative is being conducted by the Commercial Aviation Safety Team.

6. 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.

7. Matthews.

8. Air Transport Association of America. *Current Recommendations of the Commercial Aviation Safety Team (CAST): A Guide for the Airline Industry*. July 2002.

9. FAA in August 1995 issued Flight Standards Handbook Bulletin for Air Transportation (HBAT) 95-10, *Selected Event Training*. The purpose of the HBAT was to provide guidance and information about implementation of selected event training (SET). FAA defines SET as “voluntary flight training in hazardous in-flight situations which are not specifically identified in FAA regulations or directives.” Examples of SET include “false stall warning (stick shaker) at rotation; full stalls; excessive roll attitudes (in excess of 90 degrees); high pitch attitudes (in excess of 35 degrees); engine failure at low altitude and airspeed after takeoff or during go-around; [maintaining] engine-out minimum control speed on autopilot; [and] engine-out missed ILS [instrument landing system] approach with the autopilot engaged throughout.”

10. U.S. National Transportation Safety Board (NTSB). Safety Recommendation A-02-01 and A-02-02, February 8, 2002.

11. Testimony of Capt. Larry Rockcliff at NTSB public hearing on the accident involving American Airlines Flight 587, October 29 to November 1, 2002.

12. Carbaugh.

13. Funding for the program was authorized by the U.S. Congress in conjunction with the Jan. 24, 2000, enactment of the Wendell H. Ford Aviation Investment and Reform Act for the 21st Century. The act requires FAA to “work with representatives of the aviation industry … to develop specific training curricula to address critical safety problems, including problems of pilots … in recovering from loss of control of an aircraft, including handling unusual attitudes and mechanical malfunctions.”

14. Priest, Jim. E-mail communication with Lacagnina, Mark. Alexandria, Virginia, U.S. 23 November 2003. Flight Safety Foundation, Alexandria, Virginia, U.S.

15. NTSB. Aircraft Accident Report, Volume I: *In-flight Icing Encounter and Loss of Control; Simmons Airlines, d.b.a. American Eagle Flight*

4184; Avions de Transport Regional (ATR) 72-212, N401AM; Roselawn, Indiana; October 31, 1994. NTSB said, in the report, that the probable causes of the accident, in which all 68 occupants were killed, were "the loss of control, attributed to a sudden and unexpected aileron hinge moment reversal that occurred after a ridge of ice accreted beyond the deice boots because: 1) ATR failed to completely disclose to operators — and incorporate in the ATR 72 airplane flight manual, flight crew operating manual and flight crew training programs — adequate information concerning previously known effects of freezing precipitation on the stability and control characteristics, autopilot and related operational procedures when the ATR 72 was operated in such conditions; 2) the French Directorate General for Civil Aviation's inadequate oversight of the ATR 42 and 72, and its failure to take the necessary corrective action to ensure continued airworthiness in icing condition; and 3) the French Directorate General for Civil Aviation's failure to provide the [FAA] with timely airworthiness information developed from previous ATR incidents and accidents in icing conditions, as specified under the Bilateral Airworthiness Agreement and Annex 8 of the International Civil Aviation Organization."

In response to petitions for reconsideration filed by the French Directional Générale de l'Aviation Civile and Avions de Transport Regional, NTSB on Sept. 13, 2002, amended the probable cause to "the loss of control, attributed to a sudden and unexpected aileron-hinge-moment reversal, that occurred after a ridge of ice accreted beyond the deice boots while the airplane was in a holding pattern during which it intermittently encountered supercooled cloud and drizzle/rain drops, the size and water content of which exceeded those described in the icing-certification envelope. The airplane was susceptible to this loss of control, and the crew was unable to recover."

16. NTSB. Aircraft Accident Report: *Crash During Landing, Federal Express, Inc., McDonnell Douglas MD-11, N61FE, Newark International Airport, Newark, New Jersey, July 31, 1997*. NTSB said that the probable cause of the accident, in which the airplane and cargo were destroyed, and the five occupants received minor injuries, was "the captain's overcontrol of the airplane during the landing and his failure to execute a go-around from a destabilized flare." See also: FSF Editorial Staff. "Destabilized Approach Results in MD-11 Bounced Landing, Structural Failure." *Accident Prevention* Volume 58 (January 2001).

17. NTSB. Aircraft Accident Report: *Uncontrolled Descent and Collision with Terrain, USAR Flight 427, Boeing 737-300, N513AU, Near Aliquippa, Pennsylvania, September 8, 1994*. NTSB said that the probable cause of the accident, in which all 132 occupants of the airplane were killed, was "a loss of control of the airplane resulting from the movement of the rudder surface to its blowdown limit. The rudder surface most likely deflected in a direction opposite to that commanded by the pilots as a result of a jam of the main rudder power control unit servo valve secondary slide to the servo valve housing offset from its neutral position and overtravel of the primary slide." The report defined blowdown limit as "The maximum amount of rudder travel available for an airplane at a given flight condition/configuration." See also: FSF Editorial Staff. "Rudder Malfunction Causes Loss of Control of Boeing 737." *Accident Prevention* Volume 56 (September 1999).

18. NTSB said that a rudder hard-over (i.e., "movement of the rudder surfaces to their blowdown limits in a direction opposite to that commanded by the pilots") most likely was the cause of the March 1991 Boeing 737 accident at Colorado Springs, Colorado, U.S. In its final report — *Uncontrolled Descent and Collision With Terrain, United Airlines Flight 585, Boeing 737-200, N999UA, 4 Miles South of Colorado Springs Municipal Airport, Colorado Springs, Colorado, March 3, 1991* — NTSB said that the upset might have been caused by either "a malfunction of the airplane's directional control system or an encounter with an unusually severe atmospheric disturbance." NTSB did not determine conclusively the probable cause of the accident, in which all 25 occupants were killed. See also: FSF Editorial Staff. "U.S. Report: No Conclusive Evidence Found to Explain Boeing 737 Crash." *Accident Prevention* Volume 50 (May 1993).

19. NTSB. Aircraft Accident Report: *United Airlines Flight 232, McDonnell Douglas DC-10-10, Sioux Gateway Airport, Sioux City, Iowa, July 19, 1989*. NTSB said that the probable cause of the accident — in which 111 occupants were killed, 47 occupants received serious injuries, 125 occupants received minor injuries and 13 occupants received no injuries — was "the inadequate consideration given to human factors limitations in the inspection and quality control procedures used by United Airlines' engine-overhaul facility which resulted in the failure to detect a fatigue crack originating from a previously undetected metallurgical defect located in a critical area of the stage 1 fan disk that was manufactured by General Electric Aircraft Engines. The subsequent catastrophic disintegration of the disk resulted in the liberation of debris in a pattern of distribution and with energy levels that exceeded the level of protection provided by design features of the hydraulic systems that operate the DC-10's flight controls." See also: Haynes, Alfred C. "United 232: Coping With the 'One-in-a-Billion' Loss of All Flight Controls." *Accident Prevention* Volume 48 (June 1991).

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Further Reading From FSF Publications

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New Airline Pilots May Not Receive Sufficient Training to Cope With Airplane Upsets

A study conducted for the U.S. National Aeronautics and Space Administration says that, although pilots cannot be trained for all imaginable scenarios, current airplane upset-recovery training might be expanded to include more types of upset scenarios.

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From 1993 through 2002, loss of control in flight was the largest category of commercial jet fatal accidents worldwide, resulting in 2,131 fatalities.[1] One type of loss of control is an airplane upset, defined as "an airplane in flight unintentionally exceeding the parameters normally experienced in line operations or training."[2]

Precipitating factors in airplane upset accidents have included equipment failures and system anomalies, weather phenomena, inappropriate use of flight controls or systems, inappropriate control responses by the crew, or some combination of these factors. In some of these accidents, recovery from the initial upset attitude might have been possible if flight crews had promptly applied appropriate control inputs.

Recovery from airplane upsets is challenging, even for highly experienced airline pilots. The initial upset is generally sudden and unexpected; not only must the crew assess the situation quickly and correctly, but they also must implement appropriate recovery procedures. Moreover, time constraints — and, in some situations, altitude constraints — can require correct recovery procedures to be initiated with minimal delay.

Usually, the crew does not have time for the relatively slow cognitive processes of reasoning and problem solving; rather, the appropriate actions must be highly learned skilled responses that can be executed quickly. Under current airline training regimens, pilots rarely have opportunities to practice the appropriate recovery procedures. Also, recovery from some airplane upsets requires either recognizing the underlying problem that is causing the upset and is complicating the recovery or implementing a recovery technique that is robust in correcting for a broad range of underlying conditions.

The U.S. National Transportation Safety Board (NTSB) has recommended on several occasions that pilots be trained to recover from abnormal regimes of flight and unusual attitudes.[3] Both the U.S. Federal Aviation Administration (FAA) and the Air Transport Association of America (ATA; an industry association representing most U.S. major airlines and national airlines) encourage airlines to conduct airplane upset-recovery training. The FAA Handbook Bulletin for Air Transportation 95-10, *Selected Events Training*, encouraged airlines to provide training in "excessive roll attitude ... and high pitch attitude."

Many U.S. airlines now include limited training of this type, although the content and extent of the training vary widely. Typically, the training comprises a combination of classroom presentations and simulator training.

From 1996 through 1998, a consortium of three dozen organizations — including Flight Safety Foundation, manufacturers, international air carriers, pilot organizations, flight-training organizations and government and regulatory agencies — developed the *Airplane Upset Recovery Training Aid*, which includes approximately 160 pages of text and two videotapes. The content of the training aid, including recommended upset-recovery procedures, was based on a consensus among specialists. The training aid included recommended procedures for excessive nose-high attitudes and excessive nose-low attitudes.

Until recently, no formal study of the effectiveness of existing airplane upset-recovery training programs had been attempted. Supported by a contract from the U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Program, Veridian Corp. (acquired by General Dynamics in August 2003) completed a study examining some, but not all, of the relevant issues.[4] The primary objective of the study was to generate data to support decision making on the part of FAA and the airlines.

The study evaluated the flying performance of pilots in eight scenarios that were derived from upset accidents. Cost and time constraints limited the study to 40 new-hire airline pilots without military flight experience — a group of particular interest because they represent the majority of future airline pilots. The study did not address how airline captains or other more experienced pilots might perform in these scenarios.

As a group, the 40 pilots recovered more successfully from some scenarios than from others. In general, the pilots recovered most reliably from the upset scenarios that were relatively straightforward, uncomplicated and similar to the training that they had received repeatedly or early in their piloting careers. Results from these scenarios suggest that upset recovery training can be effective.

Nevertheless, most of the pilots did not recover control of the aircraft in most of the upset scenarios. Recovery was possible in each of these upsets, but some scenarios required techniques that were novel, counterintuitive or beyond the experience of airline pilots who have not been trained on the specific scenario recovery. The upset scenarios in which the pilots were least likely to recover aircraft control were scenarios for which airline pilots may receive only brief exposure or minimal training — and for which their predominant training actually conflicts with the necessary recovery procedure. Pilots in the study experienced problems in controlling the aircraft when they were surprised by the upset and when the available cues did not clearly inform them about the situation; in contrast, in most current training, the pilots are expecting upset scenarios, and the elements of surprise and ambiguity are not realistically simulated. Nevertheless, because of the difficulty of recovering aircraft control and the effects of surprise when an upset occurs during routine operations, airline pilots cannot realistically be expected to recover aircraft control with a high degree of reliability in all upset scenarios.

NASA's specific objectives in sponsoring the study were the following:

- Compare the relative effectiveness of no upset-recovery training; aerobatic training (in light aircraft); upset-recovery training in ground-based full-motion simulators; combined aerobatic training and ground simulation training; and in-flight simulation training on airplane upset recovery. (The hypothesis was that the more realistic the upset-recovery training, the better pilot performance would be.);

- Determine how well currently trained, new-hire airline pilots are able to respond to a representative set of airplane upset scenarios derived from actual accidents;

- Identify any specific weakness in pilots' upset-recovery techniques and identify areas in which current training should be improved; and,

- Determine whether recovery from some types of airplane upset scenarios is more difficult than recovery from others.

Pilots Flew the Test Aircraft in Eight Airplane Upset Scenarios

Veridian organized a workshop at the International Symposium on Aviation Psychology in May 1999 to solicit industry input to the design of this study. The workshop was attended by specialists from aircraft manufacturers, international air carriers, pilot organizations, FAA and NASA. Veridian formed a team to advise on selection of representative accident scenarios and appropriate upset-recovery procedures.

The team compiled data about potentially recoverable airplane upset accidents resulting in hull losses between 1988 and 1997 and evaluated the data for adequacy regarding the upset sequence and the ability to correctly simulate the upset sequences in flight. From these data, the eight scenarios were selected to provide a crosssection representative of the types of situations that have led to airplane upsets. The team also developed recovery procedures for each of the accident scenarios. The recovery steps identified by the team defined the "correct" recovery elements for the purpose of the study.

The 40 pilots who volunteered to participate in the study were questioned about their training and experience and then assigned to one of five groups. Each group was composed of eight pilots flying in their probationary year for airlines operating in the United States. Pilots were grouped as follows:

- No aero/no upset — Pilots without airplane upset-recovery training or aerobatic flight experience;

- Aero/no upset — Pilots without airplane upset-recovery training but with aerobatic experience. Aerobatic experience was defined as at least six hours of training and completing aileron roll, barrel roll, chandelle, cloverleaf, Cuban eight, Immelmann, lazy eight, loop, split S, and stall-turn maneuvers or experience performing in air shows or stunts in an aircraft with an FAA aerobatics waiver;

- No aero/upset — Pilots who had completed airplane upset-recovery training in both ground school and in a simulator. These pilots did not have aerobatics training or experience;

- Aero/upset — Pilots who had completed airplane upset-recovery training in both ground school and in a simulator and also had aerobatic flight experience, as defined above; and,

- In-flight — Pilots who received ground training and in-flight airplane upset-recovery training using an instrumented in-flight simulator, the Learjet 25B variable-stability in-flight simulator (IFS). The aircraft is equipped with a computer, which is programmed so that the Learjet's handling and performance characteristics resemble those of a generic swept-wing, large, twin-engine jet transport. This group did not have aerobatic experience, as defined above, or any other airplane upset-recovery training.

After the pilots were assigned to groups, their in-flight performance was evaluated in the Learjet. The right-seat pilot station has a wheel, column and rudder controls programmed to replicate the force and displacement characteristics of a large transport aircraft in pitch and roll. The aircraft's responses to control inputs were programmed to replicate the actual forces, motions and accelerations that pilots would experience in a large transport aircraft. The right seat instrument panel has an electronic visual display with attitude director indicator (ADI) and airspeed and altitude vertical readouts. Other controls (e.g., flaps) and displays (e.g., engine monitors) are standard Learjet equipment.

The right seat instrument panel of the Learjet 25B variable-stability in-flight simulator has an electronic visual display with attitude director indicator (ADI) and airspeed and altitude vertical readouts. Other controls, such as flaps, and other displays, such as engine monitors, are standard Learjet equipment. (Photo:U.S. National Aeronautics and Space Administration)

During the evaluations, the evaluation pilot (the subject in the experiment) sat in the right seat, and the safety pilot (an experienced test pilot) sat in the left seat. The safety pilot taxied and controlled the aircraft until after takeoff, set up the configuration to be simulated, monitored the aircraft and the evaluation pilot, assumed control of the aircraft if necessary, and performed final approach, landing and taxi-back. A flight-test engineer sat behind the right-seat pilot and controlled the simulation and data collection. The evaluation pilots in the study flew the aircraft using a standard vision-restriction device to simulate instrument flight rules (IFR) flight.

The Learjet has a safety monitoring system that returns configuration to normal Learjet operating and handling characteristics (Learjet safety trips), either when the safety pilot presses one of many buttons or automatically, when the aircraft exceeds preset values for various parameters. Safety trips of particular relevance to this study are acceleration limits of plus 2.8 g (i.e., 2.8 times standard gravitational acceleration) maximum and plus 0.15 g minimum, angle-of-attack limits of plus 10 degrees maximum and minus five degrees minimum, and side slip limits of plus or minus 12 degrees.

Pilots Received Familiarization Flights

The pilots in the first four groups received a 45-minute familiarization flight in the Learjet immediately before their evaluation flight. This equalized their familiarity with that of pilots in the fifth group, who received in-flight airplane upset-recovery training in the aircraft. Upset-recovery training for the in-flight group consisted of ground school instruction on relevant aerodynamic factors and appropriate upset-recovery techniques, followed by a 45-minute in-flight training session in the Learjet, with training in roll upsets, nose-low upsets, nose-high upsets, aircraft handling characteristics with degraded stability, flight control failures (including jams, hardovers and inoperative controls) and trim runaways.[5]

Pilots in all five groups completed a 1.4-hour evaluation flight in which airplane upsets were introduced during the performance of precision instrument-control tasks. The upsets were of three types (environment, component/system or aerodynamic) and were patterned after the representative set of hull-loss airplane upset accidents that had been developed by the team.

Ideally, groups should differ only on the dimension being studied (i.e., in this study, type of training). Because of practical constraints, however, the five experimental groups differed in several other dimensions. These differences occurred by chance because the study design did not control for the pilot's total flight hours, previous flight instruction or previous airline experience, type of aircraft flown or many other measures of experience that might be relevant to a pilot's ability to recover from airplane upsets. For example, the average total flight time ranged from 5,786 hours in the no aero/no upset group to 2,250 hours in the aero/upset group.

Partially as a result of the variability of pilot backgrounds within each group and among the five groups and the limited number of pilots in the study (for cost reasons), caution is required in interpreting the study's collected data. The dependent variable of greatest interest is the percentage of pilots from each training group who recovered control of the aircraft in each upset scenario. Control recovery is a dichotomous measure (i.e., pilots either recovered or failed to recover).

Typically, studies of dichotomous measures use relatively large samples to obtain statistically reliable results unless effects are quite large. The same is true for experiments, such as this one, in which a between-subjects design is used.

The performance of individual pilots varied so greatly within each group and among the five groups that there was no determination of whether the five groups differed statistically in their ability to recover control of the aircraft in these scenarios. For example, even though six of seven in-flight trained pilots recovered control of the aircraft in the "Pittsburgh" scenario and only one pilot or none of the pilots in the other four groups recovered aircraft control, this difference was not statistically significant.

Because the pilots were all newly hired pilots in their probationary year, they had limited experience in the aircraft they usually flew on the job. Hence, the results cannot be extended to make inferences about how captains and first officers with more line experience might have performed in the upset scenarios. In addition, the airplane upset-recovery training given to the evaluation pilots was brief and has been characterized as "exposure" rather than training.

The study obtained the following types of data:

- The computer recorded data about the position, motion and attitude of the aircraft; the position of controls; and the occurrence of safety trips;
- After the flight, measures of time to first control inputs, the number of first correct control inputs, the number of correct actions, time to recover control of the aircraft, the number of safety trips and altitude loss were calculated;
- For each upset-recovery attempt, whether the evaluation pilot recovered successfully was recorded;
- For each safety trip, the possibility that a safety trip might have prevented or interrupted the recovery of aircraft control was evaluated in flight by the safety pilots;
- Video and audio recordings were made of the evaluation pilot's upset-recovery actions;
- After the flight, the safety pilot rated the evaluation pilot's overall performance on four dimensions, using a five-point scale;
- The flight test engineer recorded brief comments about each pilot's performance during each scenario;
- A questionnaire was distributed to the evaluation pilots, who provided information about flight experience and training and rated forms of training. They also were given an opportunity to make comments about the evaluation flight; and,
- A post-flight debriefing was conducted in which evaluation pilots could comment on each scenario. Correct procedures for each scenario were presented to the evaluation pilot after the completion of all data collection, and interactive discussions were held, with the intention of ensuring that the evaluation would be a positive learning experience.

The assessment of successful recovery of aircraft control was performed as follows: Immediately after each recovery attempt, the safety pilot assessed the evaluation pilot's success or failure in returning the airplane safely to straight-and-level flight. Operationally, a successful recovery meant that either the safety trips were not activated, or if they were, the safety pilot believed that the evaluation pilot's control inputs would have been successful. Conversely, safety pilots classified failed recoveries as those in which the safety trips were activated without the evaluation pilot having initiated correct, positive actions, or those in which the safety pilot, noting the absence of a proper response by the evaluation pilot, took control prior to activation of a safety trip.

The upset-recovery success data were independent of the data on evaluation pilots' adherence to the individual steps of the upset-recovery procedures developed and agreed upon by the team. Further, there are no data on the accuracy of these upset-recovery procedures or on how closely pilots must adhere to the procedures (i.e., tolerances) to recover an aircraft to straight-and-level flight. In addition, data on the amplitude of pilot inputs were not collected or analyzed.

Although successful upset-recovery was the primary dependent variable in this study, performance data were collected on each of the steps appropriate for recovery of aircraft control in each of the eight scenarios; data on related variables also were collected. One example of these performance data is the elapsed time from the beginning of the upset to the first correct control input.

Researchers hoped that these data would provide a picture of the recovery actions that pilots performed well and the recovery actions that they failed to perform well. These data were intended to identify the critical differences between successful and unsuccessful recoveries. For these parameters, the data were continuous and the sample size was less problematic. Because there is a danger of random differences appearing significant when comparing groups across many variables, appropriate statistical caution was used in interpreting apparent differences in some of these variables.

In some situations, the measures of performance on individual steps in the recovery procedures did not correlate well with the overall measure of recovery/non-recovery. Part of the problem may have been that the study focused on single-point measures of control inputs and airplane dynamics and provided only limited information about the timing, sequencing and magnitudes of these pilot inputs and airplane responses.

In addition to the videotapes and audio recordings that were made of each flight and the data that were collected on control inputs and aircraft performance, the safety pilot also made brief comments after each flight. Nevertheless, the safety pilots had multiple tasks to perform during flight and could not provide detailed perspectives of each pilot's actions on each scenario.

Although these various methodological issues constrain interpretation of the data, they also provide guidance for future studies.

Scenarios Based on Eight Fatal Accidents

The eight scenarios with which pilots were evaluated in this study were based on the following fatal accidents: [6]

- Charlotte, North Carolina, U.S., July 2, 1994 — A Douglas DC-9 on an instrument landing system (ILS) approach was flown into a microburst with associated wind shear and high sink rate; [7]
- Birmingham, Alabama, U.S., July 10, 1991 — A Beech C99 on final approach was flown into a thunderstorm cell with strong vertical air shafts and associated turbulence and entered a nose-high attitude with a 45-degree left bank;[8]
- Toledo, Ohio, U.S., Feb. 15, 1992 — The captain flying a Douglas DC-8 on a second missed approach became spatially disoriented, apparently from a combination of physiological factors and a possible failed attitude indicator, and allowed the airplane to enter a nose-low steep bank. The first officer took control but was not able to recover control of the aircraft;[9]
- Shemya, Alaska, U.S., April 6, 1993 — The leading edge wing slats of a McDonnell Douglas MD-11 were inadvertently deployed in cruise flight, leading to reduced pitch stability, combined with light control forces, and resulting in violent, pilot-induced, pitch oscillations;[10]
- Nagoya, Japan, April 26, 1994 — The pilot manually flying an Airbus A300 on approach inadvertently triggered the GO lever, which changed the flight director to go-around mode and caused a thrust increase. The autopilots were subsequently engaged, while the pilot continued pushing against the control wheel. The horizontal stabilizer automatically trimmed to the full nose-up position, and the aircraft stalled;[11]
- Pittsburgh, Pennsylvania, U.S., Sept. 8, 1994 — During initial approach, pilots of a Boeing 737 experienced yaw/roll following uncommanded movement of the rudder to its blowdown limit, apparently in the opposite direction commanded by the pilots. (NTSB defined blowdown limit as "the maximum amount of rudder travel available for an airplane at a given flight condition/configuration" and said that rudder blowdown occurs "when the aerodynamic forces acting on the rudder become equal to the hydraulic force available to move the rudder.");[12]
- Roselawn, Indiana, U.S., Oct. 31, 1994 — During descent to 8,000 feet in icing conditions, the pilots of an Avions de Transport Régional ATR 72 experienced uncommanded roll and rapid descent resulting from sudden aileron hinge movement reversal caused by a ridge of ice accreted behind the deice boots;[13] and,
- Detroit, Michigan, U.S., Jan. 9, 1997 — Pilots of an Embraer EMB-120RT experienced an uncommanded roll and rapid descent caused by a thin, rough accretion of ice on the lifting surfaces.[14]

Appropriate upset-recovery techniques for each of the eight accident scenarios were developed, using the training procedures developed by American Airlines, United Air Lines, Delta Airlines and the *Airplane Upset Recovery Training Aid*. Two of the eight scenarios involved wing icing; the recovery for these two scenarios was based on advice from John Dow, an FAA aviation safety engineer.

The individual recovery steps for each scenario represent an idealized recovery technique that was developed for that specific scenario. The recovery steps were designed to facilitate data collection and analysis, and they are not necessarily consistent with the upset-recovery procedures that have been adopted by individual air carriers. Although data were collected about the pilot's performance on all of the recovery steps, some of the steps that were enumerated for each scenario were more critical than others for achieving recovery of aircraft control.

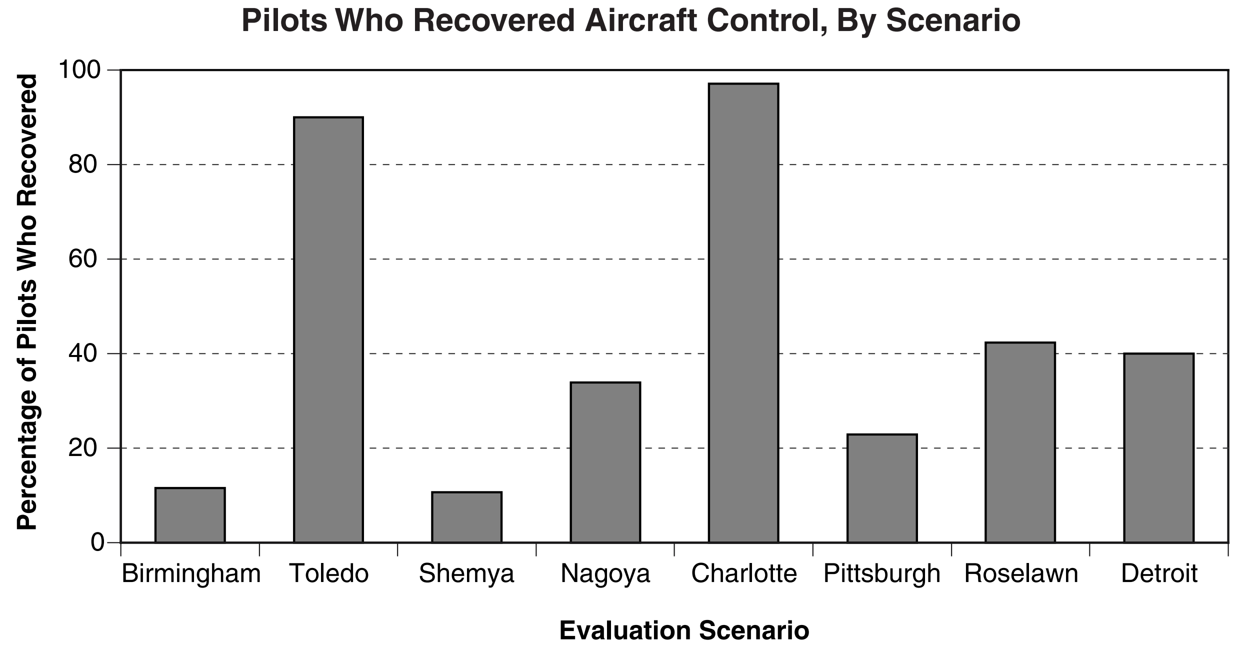
Pilot Performance Varied in Each Scenario

Performance differed considerably among the eight accident scenarios. For example, 98 percent of the evaluation pilots recovered control of the aircraft in the Charlotte scenario, compared with 11 percent in both the Shemya scenario and the Birmingham scenario (Figure 1, page 24).

Charlotte

The Charlotte scenario was presented to the pilots as a wind shear event on short final approach. The primary factor in achieving recovery was to obtain maximum thrust and maintain an angle-of-attack near stick-shaker (stall-warning) activation.

In this scenario, 97 percent of the pilots recovered control of the aircraft. The one pilot who did not complete a successful recovery was impeded by a safety trip. There were no reliable



Note: The evaluation scenarios were developed from eight airplane-upset accidents. Details of the accidents are in footnote 7 through footnote 14, beginning on page 31.

Source: U.S. National Aeronautics and Space Administration

Figure 1

differences among training groups, either with respect to recovery or to individual recovery techniques. All the pilots said that they had received substantial training in wind shear recovery. Thus, these results demonstrate the effectiveness of training for such situations.

During the recovery procedure, almost half of the pilots changed the landing-gear setting and/or the flap setting.[15] That some pilots changed flap configuration or landing-gear configuration shows that there may be (depending on aircraft type) wide margins of tolerance within which recovery of aircraft control may be achieved. None of the pilots pressed the autopilot-disconnect button, although such an action is emphasized during training on most aircraft types as an action to be taken early in any upset recovery. Pilots are encouraged to press the autopilot-disconnect button in an upset, regardless of whether the autopilot is engaged, to form a strong habit of disconnecting the autopilot before applying manual control inputs. (Pilots who overpower an engaged autopilot with their own manual inputs can, in many situations, further compromise aircraft handling and control.) The autopilot was not engaged at the beginning of the Charlotte scenario, and the pilots may have been aware of that as they began recovery procedures.

Birmingham

This scenario was presented to the pilots as an approach in the vicinity of thunderstorms with reports of moderate to severe turbulence. The underlying cause of the simulated upset was severe turbulence; the turbulence led to an airplane upset with a 45-degree bank and a nose-high attitude. The upset was not in the core of a microburst and did not require standard wind shear/microburst recovery techniques. In this scenario, holding pitch — rather than lowering the nose — resulted in stalling the airplane.

The initial conditions were a clean configuration with an airspeed of 180 knots. The aircraft was then upset with an uncommanded left roll and pitch-up, and light turbulence was simulated. The nose-up pitching moment in this scenario was strong enough that holding full nose-down elevator input was inadequate to control the pitch rate without being supplemented by applying nose-down pitch trim or rolling the airplane to divert the lift vector from the vertical.

In this scenario, 11 percent of the pilots recovered control of the aircraft. There were no reliable differences among training groups, either with respect to recovery or to individual recovery techniques.

Pilots who recovered control of the aircraft differed from those who did not only in that they had fewer encounters with safety trips. Safety pilots said that many of the safety trips that were experienced by non-recovering pilots occurred because of an absence of timely inputs. There were no significant differences in any measures of flight control inputs or other control responses.

Pilots typically responded by quickly applying aileron and rudder to correct the initial roll, but they failed to apply nose-down elevator in a timely manner, resulting in loss of airspeed that led to aerodynamic stall.

As a group, pilots appeared to respond consistently with their training to fly the airplane first for excessive bank and for microburst or wind shear recovery rather than to correct for high nose-up attitude. The introduction, as a thunderstorm scenario, apparently caused the pilots to prepare to conduct wind shear recovery procedures. Recovery from a high nose-up attitude requires applying nose-down pitch control to unload the aircraft and using bank angle to help reduce pitch attitude. Wind shear/microburst recovery emphasizes maintaining pitch near stick-shaker activation to extract as much lift as possible from a low-energy state and maintaining a wings-level roll attitude.

This scenario contrasts with the Charlotte scenario, which also was introduced as an approach in the vicinity of thunderstorms but which included a roll and high sink rate. The two scenarios require opposite pitch commands for recovery, with a similar series of precipitating events. Pilots appeared to diagnose the Charlotte scenario correctly and the Birmingham scenario incorrectly. The Charlotte scenario is consistent with wind shear/microburst training that is routinely provided throughout the industry. The Birmingham scenario, however, is consistent with airplane upset-recovery training, which is less often provided. With the thunderstorm scenario introduction, evaluation pilots appeared to initiate wind shear/microburst recovery procedures, and as a result, they did not implement corrective actions uniquely required for this accident scenario.

Toledo

The accident report said that the captain of this flight became disoriented and rolled the airplane into an upset. The first officer assumed control of the airplane and attempted recovery, but his roll-control inputs and pitch-control inputs were begun too late and were of inadequate magnitude. Investigators said that control of the airplane could have been recovered if, after rolling the airplane nearly level, the first officer had applied sufficient elevator input to obtain the airplane's maximum vertical g-load limit.

In this scenario, the evaluation pilots took over from the safety pilot as the airplane rolled from a normal level-off and left turn into a steeply banked, nose-low upset. The primary factors in recovery were to recognize the captain's incapacitation and assume control of the airplane, to roll the airplane aggressively toward wings level, to retard the throttles to avoid exceeding corner speed[16] and (only after the wings were nearly level) to apply column backpressure to obtain the airplane's maximum vertical g-load.

In this scenario, 86 percent of the pilots recovered control of the aircraft. Compared with the pilots who did not recover aircraft control, those who recovered control successfully from this scenario were more likely to reduce thrust to avoid excessive airspeed, to make the correct nose-up elevator input quickly and to impose less vertical g-loads during the recovery attempt.

Pilots who recovered control of the aircraft obtained significantly better performance on two measures of the outcome of the recovery attempt: They exceeded the 210-knot corner speed by fewer knots (35 knots, compared with 107 knots for the non-recovery group) and lost less altitude (996 feet, compared with 2,697 feet for the non-recovery group).

There were no reliable differences among training groups, either with respect to recovery or to individual recovery techniques.

After the transfer of control to the evaluation pilot was complete, this was a straightforward recovery from a nose-low, increasing-airspeed, steep-banked condition. This condition is addressed in all upset-training curricula, including the FAA instrument-rating curricula to which all pilots would have been exposed. The large percentage of pilots who successfully recovered control of the aircraft is consistent with their prior experience with this kind of upset. Most pilots in the recovery group and the non-recovery group managed the roll inputs well; however, the failure of any of the pilots in the non-recovery group to retard the throttles as airspeed exceeded the corner speed demonstrates the importance of this step in the nose-low upset-recovery procedure. The smaller values for airspeed gain and altitude loss that were obtained by the pilots who recovered successfully shows the positive effects of beginning the recovery in a timely manner.

The evaluation pilots who recovered control of the aircraft generated less vertical g-loading than those who did not recover control. Because the pilots who recovered aircraft control did not obtain the Learjet's maximum certificated (limit) load, they could have obtained somewhat better performance (i.e., less altitude loss) during recovery by pulling back farther on the column to obtain the limit load. Nevertheless, this group of pilots generated enough vertical g-loads, at the correct time, to recover control of the aircraft. The greater g-load generated by pilots who did not recover aircraft control demonstrates how use of only a single (maximum) value for g-load to represent the loads that were achieved throughout the entire recovery — as in this study — can be misleading; the timing of the g-load can be just as important as the maximum load achieved in recovering from an upset such as this one. Based on their greater altitude losses and greater airspeed deviations, the pilots who did not recover aircraft control probably obtained their maximum-recorded g-loads too late, just prior to a safety trip.

Shemya

This accident began with an uncommanded slat deployment, which caused the airplane to pitch up. The elevator control inputs made by the flight crew in response to this initial pitch-up induced nose-down and nose-up pitch-oscillation cycles. The airplane type that was involved in the accident had relatively light elevator-control forces, which were reproduced for the in-flight simulation.

The critical elements in the recovery were to disconnect the autopilot, then recognize the extreme pitch sensitivity of the airplane and recover aircraft control by using small, discrete, well-timed elevator inputs.

In this scenario, 11 percent of the evaluation pilots recovered control of the aircraft. There were no reliable differences among training groups, either with respect to recovery or to individual recovery techniques.

All the pilots who recovered aircraft control limited the magnitude of their pitch inputs, while all who failed to recover control made inputs of normal magnitude. Three of the four evaluation pilots who recovered aircraft control disconnected the autopilot prior to making their first elevator input, thereby avoiding the need to use force to overpower the autopilot while making the required, sensitive elevator inputs. One pilot recovered with the autopilot engaged through the first 25 seconds of the event.

Safety trips terminated the recovery attempt for all who failed to recover control of the aircraft. The most common reason for the safety trip was excessive positive vertical g or excessive negative vertical g.

The pilots' relatively low success rate in recovering aircraft control in this scenario is an indication of the difficulty of the scenario. There were no salient cues to the impending upset, and the required sensitivity to elevator inputs had to be recognized immediately. Comments by the pilots and the safety pilots indicated that, for best performance, the pilot would have had to anticipate the light pitch-control forces and relaxed stability characteristics of this aircraft type in high-altitude cruise flight. Failing that, pilots would have had to recognize these control characteristics from the airplane's response to their first input, and then immediately adjust the amplitude of their inputs to avoid inducing greater pitch oscillations.

Another factor in the low recovery rate may have been the lack of training for most pilots, including most of the evaluation pilots, in airplane upset recoveries that require light, careful and gentle use of the controls. In addition, most upset-recovery training emphasizes the need for maximum control inputs to obtain maximum aircraft performance, which may provide negative training for this specific recovery. Of the five groups in the study, only the in-flight training group had been exposed to reduced stability margins in actual flight, with the ability for the evaluation pilots to feel the airplane response to pitch inputs and the g-forces generated by these inputs. None of the groups, including the in-flight training group, obtained a high level of success in recovery or performed significantly better than any other group. This indicates that pilots trained under any of these programs might not be prepared to deal with an upset such as this one. Most pilots did not seem to have the knowledge or experience required to recover aircraft control after this high-altitude airplane upset.

Nagoya

The underlying cause of the simulated accident was the application of full nose-up trim, resulting from conflicting inputs from the autopilot and the first officer, combined with high thrust settings commanded by alpha floor protection (designed as wind shear protection that activates if specific parameters are exceeded) and the decision by the captain to conduct a go-around. This combination resulted in an aerodynamic stall. For the study, the entry to the upset was presented to participating pilots as an approach being conducted in an airplane that was being flown behind a heavy wide-body aircraft, with a caution for wake turbulence. In a configuration with the landing gear extended, the flaps at 20 degrees and the airspeed at 150 knots, the aircraft was upset by allowing the autopilot to apply full nose-up trim, then disconnect, resulting in excessive nose-up control forces.

The primary factors in recovery from this scenario were to input full nose-down elevator and then, recognizing that the available elevator authority was insufficient to control the airplane's nose-up pitching moment, to apply emergency trim and/or roll the airplane to divert the lift vector from the vertical.

In this scenario, 33 percent of the pilots recovered control of the aircraft. There were no reliable differences among training groups, either with respect to recovery or to individual recovery techniques.

Pilots who recovered aircraft control differed from those who did not only in the amount of time that elapsed before they called for emergency trim. Pilots who recovered aircraft control encountered no safety trips; two-thirds of those who did not recover aircraft control encountered safety trips resulting from excessive angle-of-attack. Pilots who recovered aircraft control were not statistically faster in announcing the problem or applying correct flight control inputs.

Pilots typically responded by applying elevator inputs within five seconds, with all but one applying full-forward elevator. The pilots were slower to announce the problem, however. Fourteen percent of the pilots applied aileron to control the lift vector; emergency trim was applied by less than half of the pilots, and those who applied emergency trim took an average of 12 seconds to do so.

As a group, pilots appeared to respond consistently with the training for nose-high attitudes that they had received since becoming student pilots — nose-down elevator. Nevertheless, most pilots did not implement additional corrective actions that were required for this accident scenario, resulting in safety trips for high angle-of-attack. That 86 percent of evaluation pilots (with no significant differences among the groups) did not roll the airplane to control the lift vector implies that the one-time training that the members of group three, group four and group five had received in this alternative control strategy was not effective. Also, most of the pilots were slow to recognize the need for emergency trim or to call for emergency trim. (The aircraft normally flown by some of the evaluation pilots were not equipped with an emergency-trim system similar to that installed on the Learjet, however. For these pilots, the briefing conducted before the evaluation flight about the Learjet's emergency trim constituted minimal training on this system.) Another corrective action that the pilots could have considered was to reduce thrust.

This scenario contrasts with performance observed in the Toledo accident scenario, which involved a nose-low, left-wing-down attitude possibly resulting from one pilot's spatial disorientation. There was no underlying mechanical cause or environmental cause for the upset, and all but one evaluation pilot recovered control of the aircraft. In the Toledo scenario, application of the normal control inputs solved the problem. In the Nagoya scenario, however, recovery occurred only with correction of the underlying runaway trim or use of a large bank angle to supplement full nose-down elevator input. Airplane upset-recovery training has focused on the recoveries from straightforward upset attitudes, rather than from upsets exacerbated by underlying malfunctions or other conditions that require alternatives to the application of normal control inputs. Two-thirds of the pilots failed to correct what was unique to the Nagoya scenario or to proceed to a necessary alternative strategy to regain control.

One interpretation of these data is that understanding and correcting the upset's underlying cause, which is unique to the scenario rather than generic to unusual-attitude recovery, was critical to recovery of aircraft control. Another interpretation is that the pilots generally were unable to proceed beyond their first reaction — nose-down elevator (to which all pilots are well-habituated from early stall training and for which they are reinforced by every pitch-control input) — to the second control reaction (roll to control pitch rate) that was required. More thorough training in a generic recovery that included rolling to control pitch might have provided better results without requiring pilots to understand the underlying cause of the upset.

Pittsburgh

This accident involved an uncommanded rudder deflection that led to a rapid yaw/roll to the left. The upset began with the airplane operating near the "crossover speed" for the existing configuration. (Crossover speed is the speed at which any further decrease in airspeed or increase in vertical g-load, even a full wheel input [full aileron/spoiler deflection] is not sufficient to overpower the yaw/roll moments from a fully deflected rudder.)

The primary elements in the recovery from this upset were to apply full wheel input to oppose the yaw/roll, to unload the pitch axis and to use differential-thrust inputs, if required, to regain roll control.

In this scenario, 22 percent of the pilots recovered aircraft control. There were no reliable differences among the groups, either with respect to recovery or to any individual recovery techniques. Six of the seven members of the in-flight training group, all of whom recovered aircraft control successfully, used differential thrust. This technique had been covered explicitly in the in-flight training curriculum. This training group had also been exposed to a rudder hard-over scenario.

Pilots who recovered control of the aircraft differed significantly from those who did not only in thrust delta (the difference in thrust produced by the two engines), which was an outcome of the differential-thrust technique. Of the eight pilots who recovered control of the aircraft, one unloaded pitch and increased airspeed, five used differential-thrust inputs, and two used a combined airspeed/differential-thrust method. One of the eight pilots flew the airplane at a bank angle that exceeded 70 degrees prior to regaining roll control. A primary error was failure to quickly reduce the angle-of-attack after the initial full-aileron-control input did not result in the desired effect. Few of the pilots experienced safety trips because few of the pilots used enough control input to cause a safety trip. The safety trip affected the recovery of the one evaluation pilot in the in-flight group who did not recover because of an excessive angle-of-attack.

This scenario involved an airplane upset attitude exacerbated by the malfunction of a primary flight control. Further, the crossover issue (in which adequate roll-control authority using roll control alone could be obtained and/or maintained only by unloading pitch) is not intuitively obvious to pilots. This may explain why a relatively low percentage of pilots recovered from this scenario. The success of some pilots in using the differential-thrust technique emphasizes the importance of training in the use of secondary flight controls to enhance the effectiveness of primary controls or to compensate for the failure of primary controls. The ability of the in-flight group to successfully apply this technique shows a positive training effect, although training and testing were separated by only one day. One evaluation pilot used differential thrust incorrectly, actually worsening the upset; this result explains the hesitancy of some operators to incorporate differential thrust into the recovery procedure for uncommanded yaw excursions.

The data appeared to show that the pilots who did not recover lost less altitude (603 feet) than those who recovered successfully (939 feet). This resulted from the termination of data-recording when a recovery attempt ended with a safety trip. The result implies that many pilots who failed to recover control of the aircraft would have exceeded safe operating parameters relatively early in their recovery attempts.

Roselawn

This accident scenario was presented to the evaluation pilots as a descent in icing conditions. The underlying cause of the accident was an uncommanded roll resulting from buildup of ice behind the leading edge deicing boots on the wings. For the study, with landing gear retracted and flaps extended to

20 degrees, the aircraft was upset with an aileron deflection, followed by an uncommanded roll simulating wing-ice-induced asymmetric lift.

The primary factor in recovery of aircraft control was to unload the pitch axis with nose-down elevator input. Throughout the recovery, an important response was to apply and maintain the nose-down elevator required to keep the angle-of-attack below the critical value at which the aileron deflection occurred.

Forty-three percent of the evaluation pilots recovered from this scenario. Nearly half of these were in the in-flight group, which was given training on a similar scenario in the aircraft prior to testing. (Seven of eight pilots in that group recovered.) There were no reliable differences among training groups, either with respect to recovery or to individual recovery techniques.

The actions of pilots who recovered control of the aircraft differed from the actions of those who did not in the maximum airspeed flown during recovery. Pilots who recovered aircraft control averaged 19 knots greater airspeed than pilots who did not recover control.

On average, pilots responded by quickly applying correct aileron and rudder inputs, but they were slow to apply nose-forward elevator to reduce angle-of-attack.

The pilots appeared to respond in accordance with their training for excessive bank and stall recovery, but they did not implement corrective actions uniquely required for icing-induced roll and uncommanded control movement: These two types of recoveries require different responses. Normal stall-recovery training (which trains pilots in recovering from the approach to stall) emphasizes applying maximum power and minimizing loss of altitude. In contrast, recovery from icing-induced rolls and more complete stalls requires trading altitude for airspeed.

Detroit

This accident scenario was presented to the pilots as a roll upset during approach in icing conditions. The underlying cause of the simulated accident was asymmetric lift caused by icing. The primary factor in recovery was to increase aileron effectiveness by reducing angle-of-attack and increasing airspeed.

In this scenario, 44 percent of the pilots recovered control of the aircraft. There were no reliable differences among training groups, either with respect to recovery or to individual recovery techniques.

The actions of pilots who recovered control of the aircraft differed from the actions of those who did not in that they flew the aircraft at greater airspeed. Although no other differences were statistically reliable, on average, those who recovered control of the aircraft took more time on each measure (e.g., time to announce problem, time to first correct control input). The pattern of results in this scenario is similar to that of the Roselawn scenario, which also involved icing-induced roll. In each of the two scenarios, less than half of the pilots recovered control of the aircraft. The comparison between those who were able to recover control in these two events and those who were not underscores the importance of sacrificing altitude for airspeed, and the importance of increasing airspeed and reducing angle-of-attack for effectiveness of control when surfaces are contaminated with ice.

Pilots in both the Roselawn scenario and the Detroit scenario commented on the inadequacy of standard stall-recovery training and the conflict between their training for stall recovery and the actions required in icing conditions. They described how standard training programs emphasize response to stick-shaker activation and minimal loss of altitude. Uncommanded roll and stalls resulting from ice-contaminated surfaces can occur at angles-of-attack well below stick-shaker activation and in situations in which sacrificing altitude may be the only way to reduce angle-of-attack and gain airspeed quickly enough to recover control of the aircraft.

Pilots Performed Best in Wind Shear, Nose-low Spiral

Characteristics of the accident scenarios accounted for most of the variance in recovery performance in the study. Most pilots in all five groups successfully recovered control of the aircraft in two scenarios: Charlotte and Toledo.

The Charlotte scenario was a wind shear scenario. Most airlines now provide wind shear training, and all pilots in this study had received wind shear training — some of them repeatedly — outside of upset-recovery training. Thus, the recovery data suggest that training for a specific scenario can be very effective.

In the Toledo scenario, the pilots had to take control of the aircraft from an incapacitated captain and recover the aircraft from a nose-low spiral. The data indicate that most first officers would be able to take control and recover from a nose-low, steep bank situation in which the cues are unambiguous. (The first officer who was involved in the accident probably received more ambiguous cues than the pilots in the study.)

The Charlotte scenario and the Toledo scenario required textbook application of aircraft recovery techniques (for microburst and unusual attitudes) that are reinforced throughout pilots' careers. In both scenarios, the airplane responded when the pilot used the flight controls in the normal way, as long as the pilot applied adequate control force to achieve the performance required from the airplane. The recovery rate in these scenarios was extremely high, regardless of the type of upset-recovery training or aerobatic training received by the pilots.

In contrast, the Birmingham scenario and the Shemya scenario required application of recovery techniques that were essentially different from those that have been included in training throughout pilots' careers.[17]

In the Birmingham scenario (nose-high attitude induced by strong thunderstorm turbulence), many evaluation pilots appeared to try to conduct a wind shear recovery. Applying those recovery techniques, a pilot would level the wings and hold near-stick-shaker pitch; the control-column force needed to maintain the desired pitch would vary from moment to moment depending on gusts, but the airplane would respond to the pilot's elevator inputs. But in this scenario, full nose-down column had to be applied and held. Then, immediately upon realizing that full nose-down elevator could not reduce the angle-of-attack, the pilot had to proceed to an alternative control strategy to prevent a stall (i.e., rolling the airplane to control its pitch attitude).

In the Shemya scenario (uncommanded pitch-up induced by slat deployment) — because of the light pitch-control forces, the reduced aerodynamic damping caused by low air density at high altitude — the aircraft required gentle use of the controls. Most airplane upset-recovery training emphasizes aggressively moving the aircraft back to a straight-and-level attitude. When applied in this scenario, that action leads to increasing oscillations about the pitch axis.

The recovery rate in these two scenarios was low. This is consistent with the complexity of the scenarios, the brief time available for applying the correct recovery inputs and the far lesser degree to which the pilots had obtained relevant prior training and experience.

Standard Recovery Techniques Not Always Effective

In other scenarios, the standard "textbook" recovery techniques were ineffective because of underlying changes in normal control response that initiated the upset and also complicated the recovery attempts. These scenarios required either that the pilot quickly understand the underlying cause of the upset and immediately adopt an alternative recovery procedure or that the standard recovery procedure be robust enough to be effective despite the altered control response.

For example, the Detroit scenario and the Roselawn scenario required positively reducing angle-of-attack, sacrificing altitude for airspeed during the recovery from an icing-induced stall or uncommanded roll. This is inconsistent with the typical approach-to-stall training, which emphasizes minimizing altitude loss. Pilots made proper aileron and rudder inputs in both scenarios but were slow to reduce angle-of-attack.

Similarly, the Pittsburgh scenario required reducing angle-of-attack and reducing vertical g-load to enable roll-control effectiveness or the application of alternate mechanisms for roll control because of a fully deflected and jammed rudder. Further, Nagoya required not only manipulating the controls toward an appropriate attitude but also correcting the underlying configuration problem of full nose-up trim. An alternative to correcting the trim was using roll to divert the lift vector from the vertical.

Recovery in these four scenarios ranged from 23 percent to 42 percent (in the five groups combined) and was unrelated to the type of airplane upset-recovery training or aerobatic training that the pilots had received. Most pilots had difficulty transitioning to an alternative control technique when confronted with ineffective response from the normal controls or recovery procedures.

Similar Errors Found in Multiple Scenarios

Regardless of pilots' ability to recover aircraft control, this study provides data about the kinds of errors made by evaluation pilots in all five training groups while attempting to recover from the upset scenarios. For example, each of the six scenarios in which the majority of pilots failed to recover control of the aircraft required reducing angle-of-attack.

In nose-high scenarios, the most common mistake was failing to use bank angle to change the direction of the lift vector as an alternative to the normal pitch controls. Many of the pilots had received at least some training in the use of roll to recover from a nose-high upset, but this training did not appear to have been effective. Similarly, pilots also generally failed to use secondary controls to enhance recovery (e.g., differential thrust to enhance roll control).

Most pilots in the Shemya scenario used overly aggressive control inputs. Aggressive inputs were consistent with most upset types and the associated recovery procedures, and few evaluation pilots appear to have received significant prior training or experience with the high altitude/high speed aircraft handling techniques that were more appropriate for recovering from the Shemya scenario and similar situations.

Pilots were inconsistent in pressing the autopilot-disconnect button before applying recovery control inputs. The autopilot was engaged during entry in only the Shemya scenario, but pressing the autopilot-disconnect button is trained as an immediate recovery action regardless of automation status (on most transport types). In the Toledo scenario and the Pittsburgh scenario, most pilots failed to press the autopilot-disconnect button. In the Shemya scenario and the Charlotte scenario, most pilots pressed the autopilot-disconnect button. In the Nagoya scenario, more than half of the pilots who recovered aircraft control pressed the autopilot-disconnect button; those who did delayed pressing the button for an average of 10 seconds after they tried to control the airplane's pitch-up with the elevator.

We do not know why the evaluation pilots pressed the autopilot-disconnect button in some scenarios but not others. The classroom upset-recovery training received by three groups of pilots emphasized the importance of pressing the autopilot-disconnect button, but perhaps they had not practiced sufficiently for this action to become an automatic, highly learned response that would be performed in conditions involving surprise and confusion.

In general, the pilots who failed to recover control of the aircraft displayed confusion and other stress reactions. In some situations, they appeared to freeze on the controls; in other situations, they made rapid switches between power settings, inadvertently activated controls or initiated roll oscillations. These confused reactions suggest that airplane upset-recovery training should place greater emphasis on surprise in the initial encounter with conditions that lead to upsets, rather than only emphasizing the practice of recovery techniques.

The pilots in all five groups showed substantial differences in performance, perhaps because of the substantial differences in the amount and nature of their flight experience before being hired by their current airlines. For example, the number of scenarios in which an individual pilot recovered aircraft control ranged from zero to seven; the average was 3.2 (out of eight scenarios). The variability in experience among the evaluation pilots reflects the current distribution in new-hires in U.S. airlines.

No statistically significant differences in recovery performance were found among the five groups. Nevertheless, because of the small number of pilots in this study and the large variability in performance among individual pilots, we can draw no conclusions about the question of whether the type of training received by these pilots affects performance in these types of scenarios. These results appear to indicate that current training is not adequate to enable new-hire pilots to reliably recover from all upset scenarios.

The pilots who had received upset training in ground simulators were exposed to a single session of generic training. The upset-recovery training currently provided by major airlines typically consists of four hours to eight hours of classroom training and a simulator session in which pilots are taught general methods of recovering from nose-high attitudes, nose-low attitudes and excessive bank attitudes rather than being taught more specific methods of recovery from a variety of upset scenarios. In this study, six of the eight scenarios presented the pilots with unfamiliar situations for which they had not been specifically trained; many pilots reacted to these situations with confusion and were not able to recover control of the aircraft.

The results of the study suggest methods in which current upset-recovery training might be expanded to help pilots deal with a number of unfamiliar situations.

Although it is not possible to train for all imaginable situations, a relatively small number of the classes of upset scenarios that might be relevant in most situations could be identified and pilots could be trained in how to respond to those classes of scenarios. For example, reducing vertical g-load and angle-of-attack improves control response and airplane performance in the recoveries from many scenarios.

Classroom training can help pilots identify the cues for recognizing conditions that precede classes of upsets and for distinguishing the type of recovery required. Distinguishing between situations that superficially appear similar but require fundamentally different responses should be emphasized during training. For example, recovery from fully developed stalls should be distinguished from recovery from incipient stalls, and wind shear recovery should be distinguished from recovery from nose-high situations that require reducing angle-of-attack aggressively.

Simulation training could place greater emphasis on exposing pilots to the conditions that precede upsets and to the onset of upsets, so that they can practice recognizing cues that distinguish different classes of upset. Further, if — in a particular situation — pilots would be unlikely to identify the underlying factors in the upset, they could practice control responses that are effective in recovery from a number of classes of upsets. Simulation training also should present upsets in unexpected ways so that pilots experience surprise and learn to cope with initial confusion. This would require integrating upset training with other forms of training so that pilots cannot always anticipate the upset scenario.

Upset-recovery training could be part of both initial qualification training and recurrent training, which would provide recency of experience and reinforcement.

The study leaves some basic questions unanswered:

- How extensively must pilots practice recovery maneuvers to obtain proficiency?
- How often must pilots train to maintain proficiency?
- To what extent does generic training enable pilots to recover from a wide variety of potential upset attitude scenarios?
- What are the best ways to address, in training, the factor of surprise that occurs in actual upsets?
- To what extent will training in ground-based simulators transfer appropriately to pilot performance in actual upset situations?
- What degree of fidelity is required of training simulators in reproducing the aerodynamic responses of aircraft outside normal operating parameters, and what are the methods of achieving the required fidelity?

These questions suggest areas for further research.♦

The opinions expressed in this article are those of the authors alone and do not necessarily represent the views of NASA, General Dynamics or San Jose State University. Tom Chidester and Immanuel Barshi contributed to the preparation of this article.

Notes

1. Boeing Commercial Airplanes. *Statistical Summary of Commercial Jet Airplane Accidents, Worldwide Operations, 1959–2002*. Boeing Commercial Airplanes, Seattle, Washington, U.S., 2003.

2. *Airplane Upset Recovery Training Aid*. May 12, 1998. The text portion of the training aid is available on the U.S. Federal Aviation Administration (FAA) Internet site at <www2.faa.gov/AVR/afs/afs200/afs210/index.cfm>.

   The training aid says that the following unintentional conditions generally describe an airplane upset: "Pitch attitude greater than 25 degrees nose-up, pitch attitude greater than 10 degrees nose-down, bank angle greater than 45 degrees [or] within the above parameters but flying at airspeeds inappropriate for the conditions."

3. For example, Safety Recommendation A-96-120 recommended training to recognize and recover from unusual attitudes and upsets that can occur from flight control malfunctions and uncommanded flight control surface movement.

4. Gawron, V.J. *Airplane Upset Training Evaluation Report,* U.S. National Aeronautics and Space Administration (NASA) Contractor Report 2002-211405. Moffett Field, California, U.S.: NASA-Ames Research Center, 2002. The study is available online at <www.ntis.gov>.

5. Pilots in group five (the in-flight training group) received two days of training and evaluation at Veridian facilities in Buffalo, New York, U.S. Ground school instruction was given in the morning of day one, followed by the training flight in the Learjet 25B variable-stability in-flight simulator in the afternoon. The evaluation flight was given the morning of day two. For group two, group three and group four, the interval between training and testing was much longer, ranging from seven days to 14 years.

6. Evaluation pilots were presented with the eight scenarios in counterbalanced order during their Learjet flights.

7. This accident is presented out of chronological order for convenience in discussing the results.

   The Douglas DC-9 struck trees and a private residence after the flight crew conducted a missed approach. The airplane was destroyed; 37 people in the airplane were killed, 16 received serious injuries and four received minor injuries.

   The U.S. National Transportation Safety Board (NTSB) said, in its final report, that the probable causes of the accident were "1) the flight crew's decision to continue an approach into severe convective activity that was conducive to a microburst; 2) the flight crew's failure to recognize a wind shear situation in a timely manner; 3) the flight crew's failure to establish and maintain the proper airplane attitude and thrust setting necessary to escape the wind shear; and 4) the lack of real-time adverse weather and wind shear hazard information dissemination from air traffic control, all of which led to an encounter with and the failure to escape from a microburst-induced wind shear that was produced by a rapidly developing thunderstorm located at the approach end of Runway 18R."

   The report said that contributing factors were "1) the lack of air traffic control procedures that would have required the controller to display and issue airport surveillance radar … weather information to the pilots …; 2) the Charlotte tower supervisor's failure to properly advise and ensure that all controllers were aware of and reporting the reduction in visibility and runway visual range value information and the low-level wind shear alerts that had occurred in multiple quadrants; 3) the inadequate remedial actions by [the operator] to ensure adherence to standard operating procedures; and 4) the inadequate software logic in the airplane's wind shear warning system that did not provide an alert upon entry into the wind shear."

8. The Beech C99 struck houses during an instrument landing system (ILS) approach. The airplane was destroyed; 13 people in the airplane were killed, and two received serious injuries.

   NTSB said, in its final report, that the probable cause of the accident was "the decision of the captain to initiate and continue an instrument approach into clearly identified thunderstorm activity, resulting in a loss of control of the airplane from which the flight crew was unable to recover and subsequent collision with obstacles and the terrain."

9. The Douglas DC-8 struck terrain during the second missed approach. The airplane was destroyed; four people in the airplane were killed.

   NTSB said, in its final report, that the probable cause of the accident was "the failure of the flight crew to properly recognize or recover in a timely manner from the unusual aircraft attitude that resulted from the captain's apparent spatial disorientation, resulting from physiological factors and/or a failed attitude director indicator."

10. The leading edge wing slats of the McDonnell Douglas MD-11 deployed during cruise flight at Flight Level 330 (approximately 33,000 feet). The airplane received no external structural damage, but the passenger cabin was damaged substantially; two people in the airplane were killed, 60 received serious injuries, 96 received minor injuries, and 97 were not injured.

    NTSB said, in its final report, that the probable cause of the accident was "the inadequate design of the flap/slat actuation handle by the Douglas Aircraft Co. that allowed the handle to be easily and inadvertently dislodged from the UP/RET position, thereby causing extension of the leading edge slats during cruise flight. The captain's attempt to recover from the slat extension, given the reduced longitudinal stability and the associated light control force characteristics of the MD-11 in cruise flight, led to several violent pitch oscillations. Contributing to the violence of the pitch oscillations was the lack of specific MD-11 pilot training in recovery from high-altitude upsets and the influence of the stall warning system on the captain's control responses."

    The report said that a factor contributing to the severity of the injuries was "the lack of seat restraint usage by the occupants."

11. A translation of the report by the Aircraft Accident Investigation Commission of the Japanese Ministry of Transport said that the Airbus A300 struck the ground during final approach to land at Nagoya Airport. The airplane was destroyed; 264 people in the airplane were killed and seven people received serious injuries.

    The report said that causes of the accident were the following:

    "While the aircraft was making an ILS approach to Runway 34 of Nagoya airport, under manual control by the [first officer], the [first officer] inadvertently activated the GO lever, which changed the FD (flight director) to GO-AROUND mode and caused a thrust increase. This made the aircraft deviate above its normal glide path.

"The APs [autopilots] were subsequently engaged, with GO-AROUND mode still engaged. Under these conditions, the [first officer] continued pushing the control wheel in accordance with the [captain's] instructions. As a result of this, the THS (horizontal stabilizer) moved to its full nose-up position and caused an abnormal out-of-trim situation.

"The crew continued [the] approach, unaware of the abnormal situation. The [angle-of-attack] increased, the alpha floor function was activated, and the pitch angle increased.

"It is considered that, at this time, the [captain] (who had now taken the controls) judged that landing would be difficult and opted for go-around. The aircraft began to climb steeply with a high pitch-angle attitude. The [captain] and the [first officer] did not carry out an effective recovery operation, and the aircraft stalled and [struck terrain]."

12. The B-737 struck terrain during the approach to landing at Pittsburgh (Pennsylvania, U.S.) International Airport. The airplane was destroyed; all 132 people in the airplane were killed.

    NTSB, in its final report, said that the probable cause of the accident was "a loss of control of the airplane resulting from the movement of the rudder surface to its blowdown limit. The rudder surface most likely deflected in a direction opposite to that commanded by the pilots as a result of a jam of the main rudder power control unit servo valve secondary slide to the servo valve housing offset from its neutral position and overtravel of the primary slide."

13. The Avions de Transport Régional ATR 72 struck terrain after a rapid descent following an uncommanded roll excursion. The airplane was destroyed; all 68 people in the airplane were killed.

    NTSB, in a 2002 revision of the probable cause that was included in the original 1996 accident report, said that the probable cause was "the loss of control, attributed to a sudden and unexpected aileron hinge moment reversal, that occurred after a ridge of ice accreted beyond the deice boots while the airplane was in a holding pattern during which it intermittently encountered supercooled cloud and drizzle/rain drops, the size and water content of which exceeded those described in the icing certification envelope. The airplane was susceptible to this loss of control, and the crew was unable to recover."

    NTSB said that factors contributing to the accident were "1) the French Directorate General for Civil Aviation's (DGAC's) inadequate oversight of the ATR 42 and [ATR] 72, and its failure to take the necessary corrective action to ensure continued airworthiness in icing conditions; 2) the DGAC's failure to provide the FAA with timely airworthiness information developed from previous ATR incidents and accidents in icing conditions; 3) the [FAA's] failure to ensure that aircraft icing certification requirements, operational requirements for flight into icing conditions and FAA published aircraft icing information adequately accounted for the hazards that can result from flight in freezing rain; 4) the FAA's inadequate oversight of the ATR 42 and [ATR] 72 to ensure continued airworthiness in icing conditions; and 5) ATR's [i.e., the manufacturer's] inadequate response to the continued occurrence of ATR 42 icing/roll upsets, which, in conjunction with information learned about aileron control difficulties during the certification and development of the ATR 42 and [ATR] 72, should have prompted additional research, and the creation of updated airplane flight manuals, flight crew operating manuals and training programs related to operation of the ATR 42 and [ATR] 72 in such icing conditions."

14. The Embraer EMB-120RT struck the ground during an approach to land at Detroit (Michigan, U.S.) Metropolitan Airport. The airplane was destroyed; 29 people in the airplane were killed.

    NTSB said, in its final report, that the probable causes of the accident were "the [FAA's] failure to establish adequate aircraft certification standards for flight in icing conditions, the FAA's failure to ensure that at Centro Tecnico Aeroespacial/FAA-approved procedure for the accident airplane's deice system operation was implemented by U.S.-based air carriers, and the FAA's failure to require the establishment of adequate minimum airspeeds for icing conditions, which led to the loss of control when the airplane accumulated a thin, rough accretion of ice on its lifting surfaces. Contributing to the accident were the flight crew's decision to operate in icing conditions near the lower margin of the operating airspeed envelope (with flaps retracted) and [the operator's] failure to establish and adequately disseminate unambiguous minimum airspeed values for flap configurations and for flight in icing conditions."

15. FAA Advisory Circular (AC) 00-54, *Pilot Windshear Guide*, says that during recovery from a wind shear encounter on approach, pilots should "maintain flap and gear position until terrain clearance is assured."

16. Corner speed is the lowest speed at which maximum g-force is available for maneuvering. A pilot recovering from a high speed, nose-low upset will obtain the minimum altitude loss by operating the airplane at corner speed and limiting g-loading.

17. The authors are indebted to Tom Chidester for suggesting this idea.

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More Than Half of Large Commercial Jet Accidents in 2002 Occurred During Approach and Landing

Loss of control was the category in which the most fatal accidents occurred during the 1993–2002 period. Approach-and-landing accidents were responsible for 10 of the year's 14 hull losses.

FSF Editorial Staff

Among the 30 total accidents to Western-built, large commercial jet airplanes[1] in 2002, 17 occurred during the initial approach, final approach or landing phases of flight. Those approach-and-landing accidents (ALAs) accounted for 256 of the 702 fatalities in the 2002 accident total. ALAs comprised 10 of the year's 14 hull-loss accidents.[2]

During the 10-year period 1993 through 2002, loss of control in flight resulted in the greatest number of fatalities, and controlled flight into terrain (CFIT)[3] the second greatest number (Figure 1, page 34). The largest number of fatal accidents in the period, 28, was attributed to loss of control in flight. There were 25 fatal CFIT accidents out of 109 total fatal accidents (each accident was counted in only one category). Another 17 fatal accidents were categorized as landing accidents.

The data were compiled by The Boeing Co. in its annual statistical summary of accident data.

For the 1993–2002 period, ALAs represented 59 percent of hull-loss accidents and/or fatal accidents and were responsible for 32 percent of the onboard fatalities. Accidents during the takeoff phase through climb phase were 24 percent of the total for the period and caused 45 percent of the onboard fatalities (Figure 2, page 35).

The rate of hull-loss accidents and/or fatal accidents for the period was 1.12 per million departures for scheduled passenger operations and 2.41 per million departures for all other operations.[4]

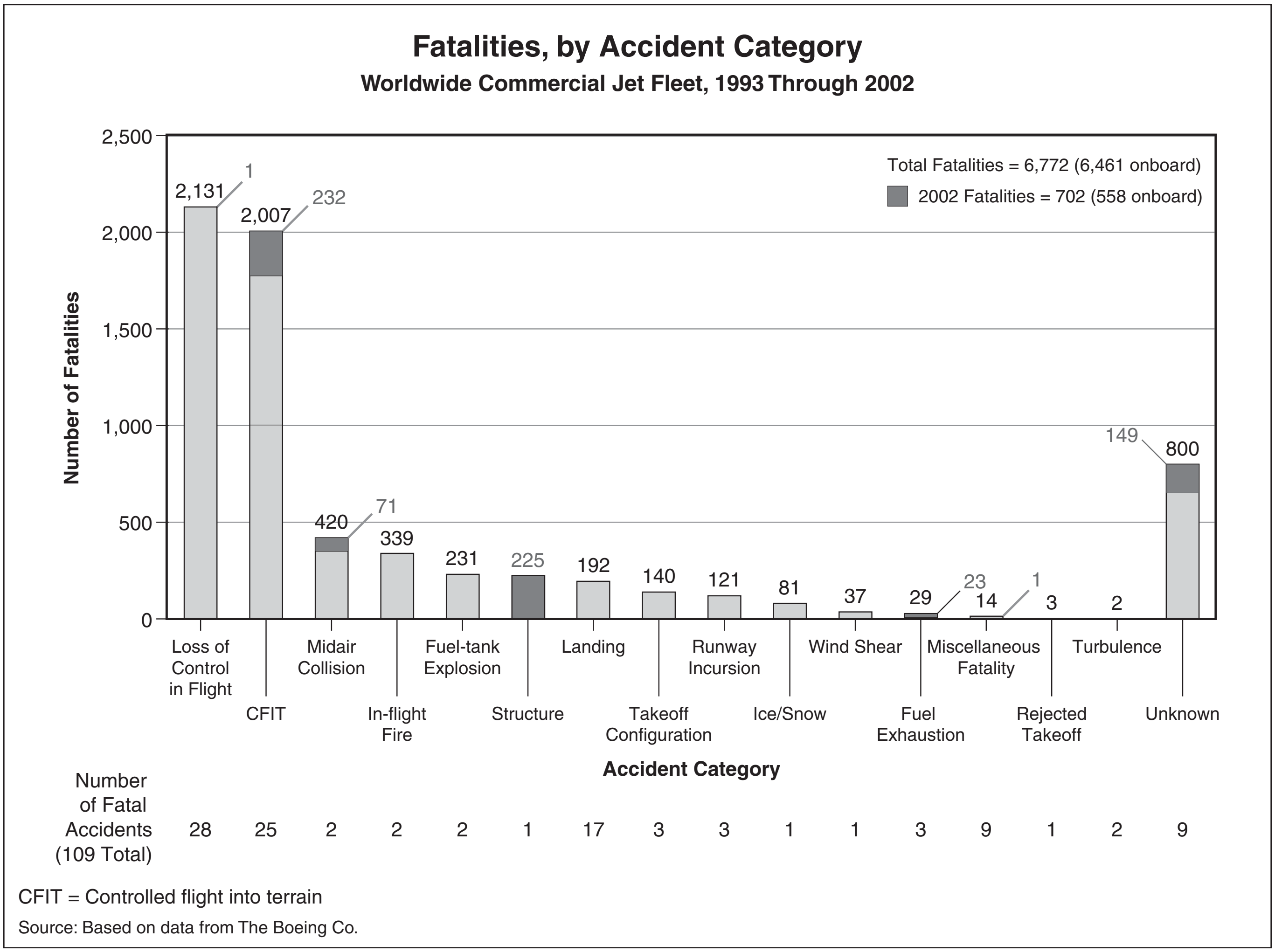
The primary causal factor was found by investigative authorities to be the flight crew in about two-thirds (67%) of the hull-loss accidents with known causes during the 10-year period (Figure 3, page 35). Airplane-related and weather-related causal factors were found to be primary in 12 percent and 10 percent of the accidents, respectively. Unlike the other hull-loss accident statistics, however, those concerning causal factors are incomplete, because a primary cause has not yet been assigned in 59 of the total 198 accidents (30 percent).

Current-model large commercial jet airplanes[5] generally continued to have the lowest rates of hull-loss accidents compared with earlier models (Figure 4, page 36). There have been no hull losses of Airbus A330, Airbus A340, Boeing 777, Boeing 737-600 through 737-900, Boeing 717 or Fokker F-70 aircraft. The BAE Systems/EADS (European Aeronautic Defence and Space Co.) supersonic Concorde had the highest hull-loss accident rate because its one hull-loss accident was divided by a relatively small number of departures.

Among the events excluded from the statistics for 2002 was one hull loss of a large commercial jet airplane, a China Northern Airlines MD-82 on May 7, 2002, which is being investigated as possible criminal action and is not classified as an accident. [The aircraft was destroyed when it struck the ocean near Dalian, China, after one of the pilots reported a fire in the cabin. All nine crewmembers and 103 passengers aboard were killed. According to unconfirmed press reports, recovered seat cushions around the most heavily burned area show evidence of a fire accelerant such as gasoline.] Also excluded, among non-hostile events in 2002, were 26 events related to severe turbulence, six to emergency evacuations, three to pushbacks and six to ground operations.♦

Notes

1. The data included commercial jet airplanes with maximum gross weights of more than 60,000 pounds (27,000 kilograms). Airplanes manufactured in the Soviet Union or the Commonwealth of Independent States (CIS) were excluded because of inadequate operational data. Commercial airplanes in military service were also excluded.
2. *Hull loss* was defined as airplane damage that is substantial and beyond economic repair. The term also included events in which the airplane was missing or substantially damaged and inaccessible.
3. 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.
4. Other operations included unscheduled passenger, charter, cargo, ferry, test, training and demonstration flights.
5. Current-model commercial jet airplanes included the McDonnell Douglas (now Boeing) MD-80, MD-90 and MD-11; the Boeing 717, 737-300 through 737-900, 757, 767 and 777; the BAE Systems BAe 146; the Avro RJ-70, RJ-85 and RJ-100; the Fokker F-70 and F-100; and the Airbus A300-600, A310, A319, A320, A321, A330 and A340.



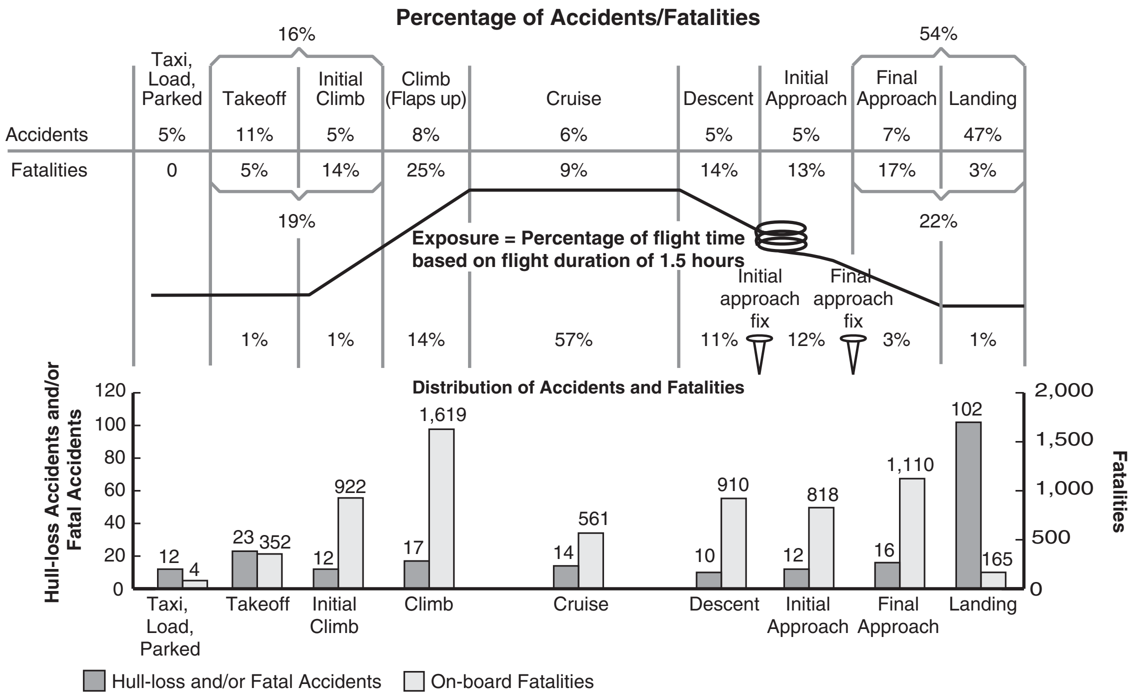
CFIT = Controlled flight into terrain

Source: Based on data from The Boeing Co.

Figure 1

Accidents and Onboard Fatalities, by Phase of Flight

Hull-loss Accidents and/or Fatal Accidents, Worldwide Commercial Jet Fleet, 1993 Through 2002



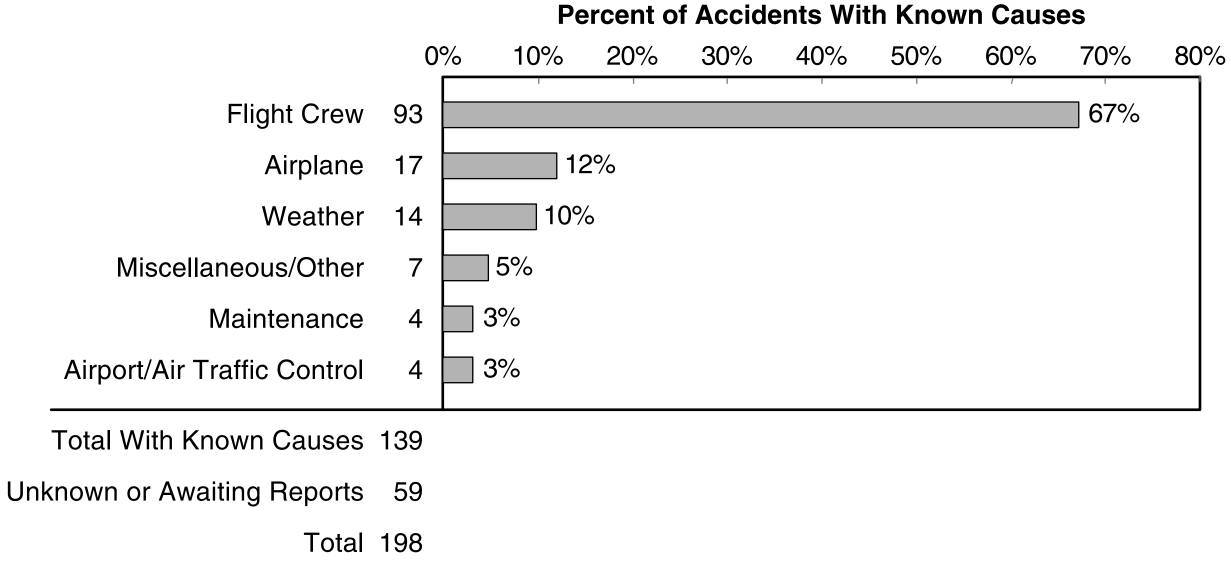
CFIT = Controlled flight into terrain

Source: Based on data from The Boeing Co.

Figure 2

Accidents, by Primary Cause[1]

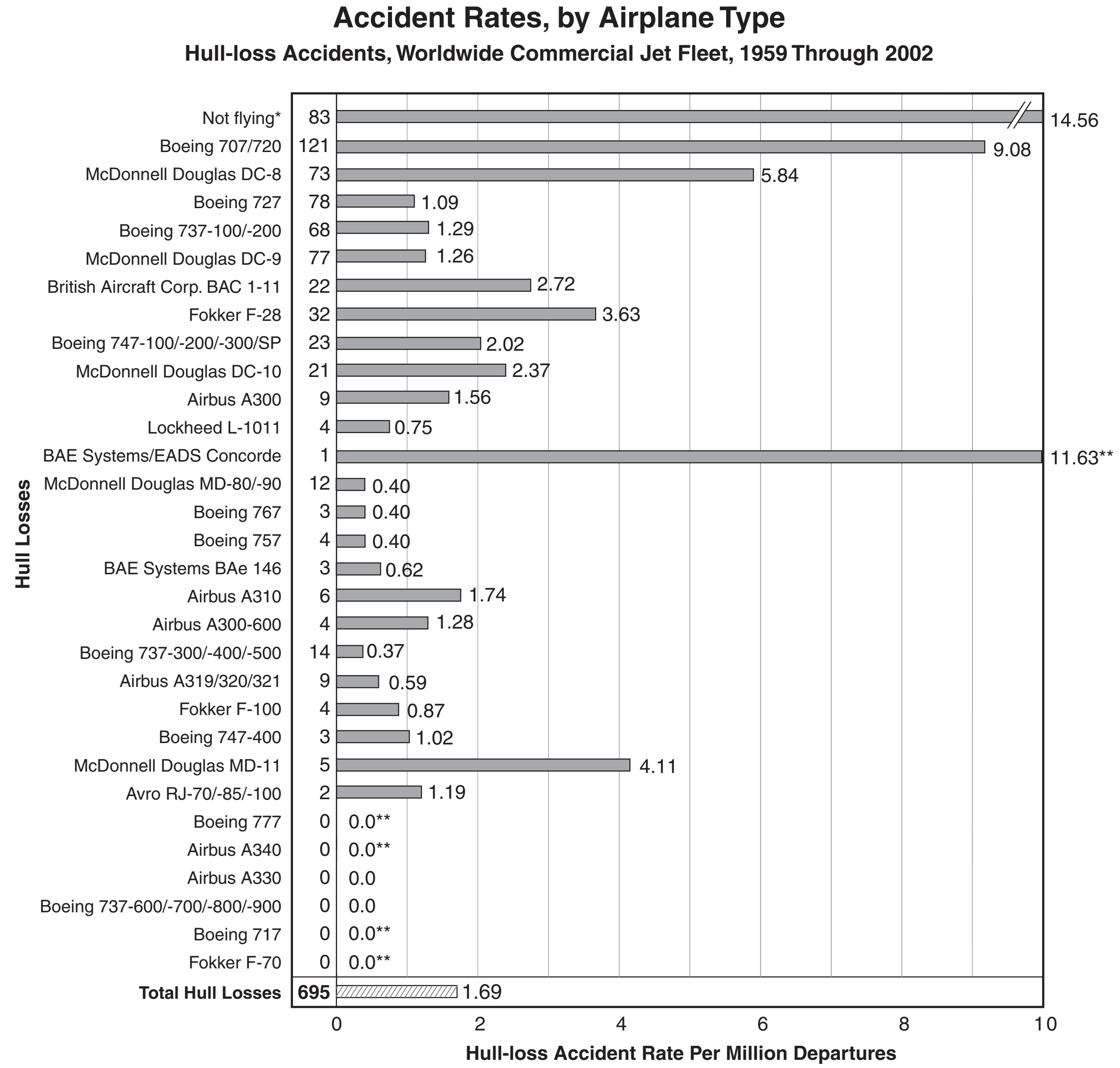
Hull-loss Accidents, Worldwide Commercial Jet Fleet, 1993 Through 2002



[1] Primary causes are those determined by the investigative authority.

Source: Based on data from The Boeing Co.

Figure 3



*The de Havilland Comet, Convair CV-800/-990, SUD-Aviation Caravelle, Breguet Mercure, SUD-Aviation Trident and Vickers VC-10 are no longer in commercial service and are combined in the "not flying" bar.

**These types have accumulated fewer than one million departures.

Source: Based on data from The Boeing Co.

Figure 4

Publications Received at FSF
Jerry Lederer Aviation Safety Library

Future-aviation Workshop Focuses on 'Post–Sept. 11' Operating Environment

Speakers said that "more than ever before, all segments of aviation are moving faster than public policy and our current ability to anticipate the future."

FSF Library Staff

Reports

Future Aviation Activities: 12th International Workshop. National Research Council (NRC), Transportation Research Board (TRB), January 2003. Circular No. E-C051. 146 pp. Figures, tables, appendixes. Available from Transportation Research Board.*

The NRC is the principal operating agency of the National Academy of Sciences, a nonprofit, quasi-government organization created by the U.S. Congress to advise the government on science and technology. The TRB, a division of the NRC, is charged with promoting innovation and progress in transportation. The workshop is conducted biennially, with the support of the U.S. Federal Aviation Administration (FAA), to forecast trends and developments in commercial, business and personal air transport. FAA asked workshop participants to examine and challenge all aspects of its draft forecast.

This circular contains presentations by speakers who "informed workshop participants that more than ever before, all segments of aviation are moving faster than public policy and our current ability to anticipate the future." The circular also contains summaries of nine discussion panels comprising 150 international participants. The panel members, representing many facets of aviation, were asked to focus on the post–Sept. 11 environment. [Post–Sept. 11 refers to the time following the terrorist hijackings and subsequent destruction of four U.S. aircraft in 2001. As of Oct. 29, 2003, 2,995 people, including the passengers and crew aboard the hijacked airplanes, were presumed killed as a result of the four hijackings. Fatalities aboard the airplanes included 232 passengers (including the hijackers), 25 flight attendants and eight pilots.]

The Domestic Airlines Panel examined influences on airline profitability and implications of industry-wide decline in revenues. The International Airlines Panel examined FAA's forecast for international aviation activity and discussed projections for and against global economic recovery. The Air Cargo Panel examined factors that could strengthen or threaten air cargo demand. The Airports and Infrastructure Panel identified factors, such as increased use of regional jets and business jets, that could influence the number of commercial passenger enplanements and total aircraft operations. The Fleets and Manufacturers Panel considered short-term and long-term economic stability and growth in aircraft manufacturing and engine manufacturing. The Regional Airlines Panel, Business Aviation Panel and Vertical Flight Panel were relatively optimistic about overall healthy growth rates.

Specific suggestions arising from discussion panels help FAA with its forecasting methodology and provide perspective based on personal expertise and knowledge. FAA uses these forecasts for budget planning, staff planning and cost-benefit analysis for rulemaking.

Books

Ground Studies for Pilots: Flight Planning. Sixth edition. Swatton, Peter J. Oxford, England: Blackwell Science, 2002. 262 pp. Figures, tables.

The book is written for students preparing to obtain commercial pilot licenses or airline transport pilot licenses. The book follows the Joint Aviation Requirements (JARs) for flight crew licensing (FCL), and like other books in the series, matches students' learning objectives with Joint Aviation Authorities syllabuses. As the title indicates, chapters focus on flight planning — navigation, meteorology, visual flight rules and instrument flight rules, fuel requirements and fuel planning, computer-generated flight plans, submission of flight plans to air traffic services, and extended-range twin-engine operations. Liberal use of examples and practice exercises is designed to help develop skills, such as chart reading and calculations, required by the JARs FCL examination.

Destination Disaster: Aviation Accidents in the Modern Age. Brookes, Andrew. Hersham, Surrey, England: Ian Allen Publishing, 2002. 164 pp. Photographs, diagrams, glossary.

Despite its title, the book acknowledges the safety of contemporary flight — "more people die from falling down stairs than from air crashes," says the author. The book's purpose, he says, is "to outline the background behind the most dramatic and noteworthy of recent flying accidents, to show the causes and to say what is being done to stop such accidents from happening again." The author is a 3,500-hour pilot who serves as aerospace analyst at the International Institute for Strategic Studies.

Narratives of aviation accidents are supplemented by photographs of accident scenes and of the aircraft types involved (including some of the accident aircraft, taken before the event), airport diagrams and flight-path diagrams.

Most of the material covered in this book will be familiar to accident investigators. This is a study for nonspecialists of various factors that caused accidents.

Regulatory Materials

Pilot Guide: Flight in Icing Conditions. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 91-74. Dec. 12, 2002. 96 pp. Figures, appendixes. Available from GPO.**

The AC is intended to be a convenient resource for pilots of airplanes operating under U.S. Federal Aviation Regulations (FARs) Parts 91, 121, 125 and 135. It provides information on principal factors related to flight in icing conditions — atmospheric conditions; icing effects, protection and detection; flight planning; in-flight operations; and icing considerations for phases of flight.

"Of particular importance are proper operation of ice-protection systems and any airspeed minimums to be observed during or after flight in icing conditions," the AC said. "There are some icing conditions for which no aircraft is evaluated in the certification process, such as SLD [supercooled large drop: a supercooled droplet having a diameter greater than 0.05 millimeter (0.002 inch)] conditions within or below clouds, and sustained flight in these conditions can be very hazardous."

The appendixes contain information on icing accidents, regulatory issues, checklists and recommended information supplements. Recommended reading includes "Protection Against Icing: A Comprehensive Overview" (*Flight Safety Digest*, June–September 1997). The AC is printed in a small-booklet format that facilitates placing it in flight manuals, flight cases or flight bags.

Management of Passengers Who May Be Sensitive to Allergens. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 121-36. Dec. 31, 2002. 6 pp. Available from GPO.**

The AC provides guidance about air carrier passenger-handling procedures for persons who are allergen-sensitive (that is, allergic to substances such as animal dander and peanuts). This guidance applies to U.S. Federal Aviation Regulations (FARs) Part 121 operators and Part 135 operators; directors of operations, safety and training; crewmembers; FAA aviation safety inspectors for cabin safety and operations; aviation medical equipment suppliers and training providers; and passengers who may be sensitive to allergens. The AC is written in a question-and-answer style for quick reference and identifies related ACs and other materials.

Peanut allergies are among those that have caused the most concern among passengers. The AC advises passengers that some airlines do not serve peanut snacks and that some airlines will substitute another snack if they are advised before the flight that a passenger with a peanut allergy will be aboard. But there is no way to guarantee a peanut-free flight, the report said, because peanuts may be one ingredient in a meal, or passengers may bring aboard their own peanut snacks.

The AC recommends that air carriers do the following:

- "Educate your personnel regarding the basis for passenger concern in this area;
- "To accommodate peanut-free food requests, review systems that you may already have in place to address special passenger dietary needs; [and,]
- "Train your crewmembers to respond quickly and properly to a passenger who may be experiencing an allergic reaction (if you choose to have crewmembers medically assist passengers)."

Management of Passengers During Ground Operations Without Cabin Ventilation. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 121-35. Jan. 16, 2003. 3 pp. Available from GPO.**

To ensure that aircraft cabins are well ventilated at all times, the AC offers guidance on air carrier procedures for ground-based air conditioning and management of passengers during ground operations when there is no cabin ventilation. A list of operational factors and safety considerations to determine the need to deplane passengers is included.

"Air carriers whose airplanes do not have the systems to provide cabin ventilation on the ground should carefully consider the possible adverse effects of periods of time on the ground without cabin ventilation," said the AC. "Airplanes that have systems to accommodate cabin ventilation and cooling on the ground should use full ventilation; a failure or shutdown of the ventilation system should trigger active passenger management, such as passenger removal, or the introduction of ground carts."

The AC recommends that air carriers develop procedures for deplaning passengers within 30 minutes if the ventilation system fails when the airplane is on the ground.

FAA issued this AC in response to one of 10 recommendations made in 2001 by the Committee on Air Quality in Passenger Cabins of Commercial Aircraft, U.S. National Research Council, in its report, "The Airliner Cabin Environment and the Health of Passengers and Crew." The AC is of interest to U.S. Federal Aviation Regulations (FARs) Part 121 and Part 135 air carrier certificate holders; FARs Part 125 certificate holders; directors of operations, safety and training; crewmembers; and FAA aviation safety inspectors for cabin safety and operations.

Developing and Implementing a Continuing Analysis and Surveillance System. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 120-79. April 21, 2003. 52 pp. plus appendixes. Available from GPO.**

A continuing analysis and surveillance system (CASS) is required for certain types of air carriers and commercial operators under U.S. Federal Aviation Regulations (FARs) Part 121.373 and Part 135.431. A CASS is a quality-management system that monitors and analyzes the performance and effectiveness of inspection and maintenance. This AC is designed as guidance for any operator that develops a CASS, whether or not it is required to do so.

The regulations require a CASS to address two basic questions:

- "Are you following your inspection and maintenance manuals and procedures?" [and,]
- "In following your manuals and procedures, are you producing consistently airworthy aircraft?"

Among other goals, the AC says, a CASS can enable a carrier to assess its safety attributes, which FAA defines as follows:

- Authority. There is a clearly identifiable, qualified and knowledgeable person with the authority to establish and modify a process;
- Responsibility. There is a clearly identifiable, qualified, and knowledgeable person who is accountable for the quality of a process;
- Procedures. There are documented methods for accomplishing a process, which answer the basic questions of who, what, when, where and why;
- Controls. There are checks and restraints designed into a process;
- Process measurement. The air carrier measures and assesses its processes to identify and correct problems or potential problems; and,
- Interfaces. The air carrier identifies and manages the interactions between processes.

The AC says, "The analysis and surveillance should not be perceived or intended as a method of identifying individuals who have committed errors, simply to take some sort of disciplinary action. The question for a CASS to answer is how to better design the inspection and maintenance programs to preclude errors from encroaching on system safety or resulting in noncompliance."

Acceptance and Use of Electronic Signatures, Electronic Recordkeeping Systems, and Electronic Manuals. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 120-78. Oct. 29, 2002. 18 pp. Appendixes. Available from GPO.**

This AC provides guidance on the acceptance and use of electronic signatures in electronic recordkeeping systems; electronic maintenance manuals and inspection-procedures manuals; quality assurance; operations manuals; and training manuals. An electronic system accepted by FAA may be used to generate aircraft records, such as load manifests, dispatch releases, aircraft maintenance records, maintenance task cards, pilot training records, flight releases, airworthiness releases and other information when these records can be authenticated by electronic signature.

For the purposes of this AC, "electronic signature" refers to either electronic signatures or digital signatures that are the equivalent of an individual's handwritten signature. "An electronic signature should retain those qualities of a handwritten signature that guarantee its uniqueness," says the AC. "A signature should identify a specific individual and be difficult to duplicate. … An acceptable method of proving the uniqueness of a signature is by using an identification and authentication procedure that validates the identity of the signatory."

Examples of authentication procedures given in the AC include codes read from badges, cards, cryptographic keys or other objects; personal identification numbers (PINs); and physiological characteristics such as fingerprints, handprints or voice patterns.

This AC applies to operators and air carriers operating under U.S. Federal Aviation Regulations (FARs) Parts 91, 121, 125,129, 133, 135 and/or 137; persons performing airmen certification under FARs Parts 61, 63, 65, 141 or 142; individuals performing maintenance or preventive maintenance under FARs Part 43; and repair stations operating under FARs Part 145.♦

Sources

* Transportation Research Board
500 5th Street, NW
Washington, DC 20001 U.S.
Internet: <http://www.TRB.org>

** Superintendent of Documents
U.S. Government Printing Office (GPO)
Washington, DC 20402 U.S.
Internet: <http://www.access.gpo.gov>

Accident/Incident Briefs

A330's Tail Strikes Runway After Rotation at Low Airspeed

The report said that the first officer inadvertently entered an incorrect takeoff decision speed (V_1) into the airplane's multipurpose control display unit. Neither pilot detected the error.

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

Cabin Crewmember, ATC Reported Tail Strike

Airbus A330. Substantial damage. No injuries.

During a morning takeoff from an airport in Germany for a flight to Canada, the underside of the airplane's tail struck the runway. The flight crew did not detect the tail strike; air traffic control (ATC) and a cabin crewmember told the flight crew during departure about the tail strike.

The flight crew requested a holding pattern while they evaluated the situation and, after a discussion with representatives of their company, decided to return to the departure airport. They received ATC vectors for an instrument landing system (ILS) approach. After they had established the airplane on the localizer at 4,000 feet and about 17 nautical miles (31 kilometers) from the runway threshold, with the autopilot engaged, the airplane pitched 26.7 degrees nose-up.

The crew disconnected the autopilot, regained control of the airplane and hand-flew the airplane for the remainder of the approach and landing.

The captain had 21,000 flight hours, including 300 flight hours as captain on the A330; the first officer had 14,000 flight hours, including 2,000 flight hours as captain on the A330. Both were company check pilots. During the incident flight, the captain was conducting a re-qualification route check on the first officer.

An investigation revealed that the first officer — the pilot not flying (PNF) — had inadvertently entered an incorrect V_1 (defined in the accident report as takeoff decision speed) of 126 knots into the multipurpose control display unit (MCDU); the entry should have been 156 knots. Rotation speed (V_R) was correctly entered as 157 knots. The report said that the error "was not detected by either flight [crewmember], despite numerous opportunities."

MCDU data are used by the PNF as references for "V_1" and "rotate" calls during takeoff, and the airspeeds are displayed on both primary flight displays. The report said that in most A330 takeoffs, the two airspeeds are separated only by one knot or two knots, and the PNF calls "V_1" and "rotate" in quick succession.

"In this occurrence, the PNF called 'V_1' as the speed reference index approached [126 knots] and 'rotate' immediately after. This prompted the PF [pilot flying — the captain] to initiate the rotation well below the calculated V_R."

Data from the flight data recorder showed that the PF began the rotation at an airspeed of 133 knots.

The report said that the pitch-up event during the approach probably resulted from the distortion by a taxiing aircraft of the glideslope signal. The distortion resulted in erroneous information to the autopilot.

Although a note on the approach chart mentioned the possibility of interference with the glideslope signal, ATC had not told the flight crew of the possibility because their aircraft was 17 nautical miles from the runway threshold; ATC procedures require that crews of aircraft that are within 12 miles [22 kilometers] of the runway threshold be told of the possibility of glideslope-signal interference.

"No warnings in the cockpit were provided to the flight crew indicating that the on-board equipment was receiving a false glide-path signal," the report said. "Had the flight crew noted the information depicted on the approach plate, it is likely that the PF would have been better prepared and reacted accordingly."

The report said that the "flat authority gradient [the similarity in flight hours and experience of the two pilots] contributed to a more relaxed attitude toward cross-checking each other's actions or confirming other information."

Haze in Cabin Prompts Airplane Evacuation

BAE Systems 146. Minor damage. No injuries.

While the airplane was being taxied for takeoff from an airport in Australia, the flight crew observed a "Low Quantity" warning light on the master warning-system panel for the "yellow" hydraulic system. About the same time, a cabin crewmember told the flight crew that there were fumes and a "slowly moving white haze" in part of the right side of the cabin; an off-duty cabin crewmember said that some passengers were having difficulty breathing.

The flight crew stopped the airplane on the taxiway and told cabin crewmembers to evacuate passengers through evacuation slides at the left doors. The two cabin crewmembers supervised the evacuation with help from two off-duty cabin crewmembers and without requesting assistance from able-bodied passengers. Two evacuated passengers received medical assistance.

Cabin crewmembers who had inhaled the fumes said that later in their tour of duty, they experienced side effects, including "extreme tiredness, sore muscles and minor throat and chest problems."

The report said that company emergency procedures required that the flight crew don oxygen masks whenever smoke or fumes were detected in the cabin and that the flight-deck door remain closed to prevent the flight crew from breathing the fumes and becoming incapacitated.

"The pilot reported that the flight crew did not don oxygen masks as there were no fumes in the area and because the urgency of the cabin crew messages conveyed the need for an immediate evacuation," the report said. "The cabin crewmember reported that it was quicker to open the flight deck door [than to communicate using the interphone] and safe to do so, as there were no fumes in the area."

The investigation revealed that a leak in a hydraulic coupling had allowed fluid under pressure to escape into the hydraulic bay and enter the passenger cabin through gaps in the sidewall lining. The coupling's o-ring seal was replaced, and the leak stopped. The leak recurred after a number of additional flights, and a subsequent inspection revealed a crack in the coupling, which then was replaced. The crack had occurred because of the failure of the coupling threads as a result of overload, which was "consistent with having been done up too tightly," the report said.

The report said that the crack may have existed at the time of the initial repair and may have gone unnoticed because replacement of the o-ring seal appeared to solve the problem.

Before the incident, the aircraft manufacturer had issued three service bulletins that required or recommended action to improve the sealing between the hydraulic bay and the cabin; the operator had implemented actions described in the first two service bulletins and had scheduled action on the third bulletin.

As a result of the investigation, the operator accelerated implementation of all three service bulletins, inspected its fleet and found no additional coupling failures. The operator also recommended the use of able-bodied passengers whenever possible to assist at the base of a slide during an evacuation and was considering requiring a "stand down of crews" after an emergency.

Captain Fractures Skull in Fall From Air Stairs

Boeing 737. No damage. One serious injury.

After a midday flight from England to Scotland, the airplane was landed and was taxied to a gate, where passengers deplaned and the crew completed shutdown checks. Because the next crew was not scheduled to arrive until later in the day, the captain told the crew to secure the airplane. (Standard company procedures are for the doors to be closed and the air stairs to be retracted.)

The report said, "Prior to leaving the aircraft, the crew assembled at the foot of the air stairs at the forward, left door (L1 door), and the commander climbed the stairs in order to close that door. [While] shutting the door, he lost his balance and fell, head first, through the gap in the right-hand rails onto the tarmac approximately two meters [seven feet] below."

The captain was taken to a hospital for treatment of a fractured skull.

An investigation determined that there had been three previous reports of people — two cleaners and one maintenance technician — falling from the air stairs, probably while operating the door.

After the incident, the operator revised the procedure for securing unattended Boeing 737 airplanes. Instead of closing the L1 door from the air stairs, the door is secured from inside the airplane, and then the crew leaves the airplane using the rear steps. After they close the rear door, the steps are removed.

Air Taxi
Commuter

Wind Blows Baggage Trailer Into Airplane's Wing

Embraer ERJ-135ER. Minor damage. No injuries.

The airplane was being taxied to the gate after a night landing at an airport in Scotland. Wind velocity was reported at 28 knots. While taxiing the airplane, the captain saw a "flicker of light" to his right. He then observed a baggage trailer moving across the apron (ramp) toward the airplane. The baggage trailer struck the airplane's right wing, then continued across the apron and struck a parked fuel truck.

An investigation revealed that the baggage trailer had been in use at a nearby gate. The baggage trailer's parking brake normally is activated when the tow bar is positioned vertically, but a ramp agent had observed that the parking brake had not been applied because of a defect in the latch that holds the tow bar in the vertical position. The ramp agent used a chock to prevent the trailer from moving as baggage was loaded into an airplane at the gate, and after loading was completed, he asked a colleague to reposition the baggage trailer at the next gate.

The report said, "Since the brake was defective, the [colleague] positioned the trailer with its front wheels at right angles to the wind, but the wheels were not chocked. The loading team then left the ramp to collect gate baggage, and it was in their absence that the trailer was blown across the apron."

After the incident, the apron-service company said that the staff would receive recurrent training on defect-reporting procedures and the management would "reinforce operational and procedural responsibilities during aircraft turnarounds, particularly in bad weather. In addition, the company will carry out a review of local strong wind procedures."

Failure of Mixture-control Cable Cited in Loss of Engine Power

Cessna 206. Destroyed. No injuries.

After the pilot leveled the airplane at 7,500 feet during a domestic flight in Australia, an uncommanded power reduction occurred. The pilot established the airplane in a glide; declared mayday, an emergency condition; and conducted emergency checks.

The report said, "As he pulled on the mixture control, it came out of the instrument panel. The pilot pushed it back into the panel and continued with the checks."

The pilot attempted to land the airplane on an airstrip, but the airplane struck trees at the approach end of the runway, touched down on all three wheels, then struck a log and flipped upside down.

A maintenance inspection revealed that the mixture-control cable had failed at its crimp fitting. The failure caused the mixture control to move to a "lean" setting, providing insufficient fuel for the engine.

Corporate
Business

Airplane Strikes Terrain During Emergency Landing

Beech B60 Duke. Destroyed. One serious injury.

Instrument meteorological conditions prevailed and an instrument flight rules flight plan had been filed for the domestic flight in the United States. The pilot said that he was flying the airplane at the initial cruising altitude of 16,000 feet, occasionally in clouds, when he observed a decrease in engine oil temperature, although the temperature remained within acceptable limits. Outside air temperature decreased from minus 20 degrees Celsius (C; minus four degrees Fahrenheit [F]) to minus 40 degrees C (minus 40 degrees F). The left engine began to vibrate.

The pilot decided to land the airplane at an en route airport. He then observed that the left-engine-turbocharger turbine-inlet temperature had decreased and that the fuel flow on the left engine was near zero. The pilot tried unsuccessfully to feather the left propeller.

He then heard a loud "pop" from the right engine, which previously had been operating normally, and told air traffic control (ATC) that he wanted to land the airplane at a closer airport. He received ATC vectors for an instrument approach to the airport. Later, the pilot said that the airplane was "midfield and low" after emerging from the clouds.

A preliminary report said, "He could see the departure end of the runway ahead, and as [the airplane] passed over the departure end of the runway, he initiated a right turn of 180 degrees. During the turn, the airplane continued to descend, and he leveled the wings and let the airplane settle into an area of small trees."

The weather included visibility of one statute mile (1.6 kilometers), a ceiling of 1,100 feet with broken clouds and an overcast layer at 1,500 feet. The 6,499-foot (1,982-meter) runway had high-intensity runway-edge lights and a four-box visual approach slope indicator (VASI) with a three-degree glide path.

Cracked Bolt Cited in Landing-gear Collapse

Piper PA-23-250 Aztec. Minor damage. No injuries.

As the airplane was being turned left from a taxiway onto a runway for departure from an airport in Canada, the left-main landing gear collapsed. The propeller struck the ground, and the left flap was damaged by contact with the wheel.

A preliminary report said that a pre-existing crack in a bolt in the linkage system of the left-main landing gear caused the failure of the bolt and the subsequent collapse of the landing gear.

Other General Aviation

Replica of Wright Brothers Airplane Strikes Trees During Taxi Tests

Virginia Aviation Wright Model B. Substantial damage. One serious injury.

Visual meteorological conditions prevailed at an airport in the United States as the pilot conducted a series of high-speed taxi tests on the airplane, a homebuilt Wright Model B — a replica of the airplane produced by the Wright Brothers.

The pilot said later that he experienced "serious directional stability problems" with the airplane and that, during taxi, the airplane suddenly became airborne. As the pilot maneuvered for landing, the airplane struck trees.

Winds at an airport eight nautical miles (15 kilometers) southwest of the accident site were calm at the time of the accident.

Overloading Cited in Emergency-landing Accident

Cessna U206F. Destroyed. Three serious injuries, three minor injuries.

Visual meteorological conditions prevailed for the morning departure from an airport in Tanzania for an 80-minute flight. The airport elevation is 4,550 feet above sea level, and the temperature 35 minutes before the accident was 22 degrees Celsius (72 degrees Fahrenheit).

The pilot's pre-takeoff power checks were satisfactory. The pilot said that after takeoff, she observed that the airplane's climb performance was inadequate and that the indicated airspeed was about 90 knots, compared with the typical climb speed of 95 knots to 100 knots.

"As the flight progressed, the pilot realized that the aircraft was not climbing; instead, it was sinking," a preliminary report said.

The pilot maneuvered the airplane several times to avoid rising terrain. About 20 minutes after takeoff, the airplane came "dangerously close" to terrain as the pilot maneuvered the airplane to avoid a hill, the report said. The pilot then conducted an emergency landing on a maize plantation. Before touchdown, the airplane struck a small tree. After all passengers had exited the airplane, the pilot called air traffic control on her mobile telephone to report the accident.

A preliminary investigation revealed that the airplane's fuel tanks had been full before takeoff. In addition to the pilot and five passengers, the airplane had been loaded with "unspecified quantities of provisions, three boxes of electrical cables, skin cream bottles and other luggage," a preliminary report said.

The passengers and baggage had not been weighed before takeoff. Investigators estimated that the takeoff weight of the airplane — including fuel, the pilot and five passengers but excluding baggage — was 3,681 pounds (1,670 kilograms). The maximum allowable takeoff weight was 3,600 pounds (1,633 kilograms).

The report said that the airplane's climb performance was "typical of an overloaded aircraft." The investigation was continuing.

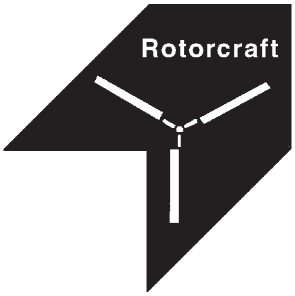
Throttle Failure Cited in Pilot's Inability to Reduce Engine Speed

Cessna 172. No damage. No injuries.

The airplane was being flown to an airport in Canada for a night landing. The pilot said that he was unable to reduce engine speed below 2,000 revolutions per minute. On short final, he shut down the engine to maintain the recommended landing speed.

The pilot said that after landing, the throttle operated normally, and he taxied the airplane off the runway.

The operator said that the throttle accelerator tube had broken and had lodged in the carburetor butterfly valve assembly, causing the throttle to stick. The operator said that this occurrence was the second of its type. The investigation was continuing.



EMS Helicopter Strikes Tree During Departure From Road

Bolkow BO 105DBS-4. Minor damage. No injuries.

The helicopter was being flown on an afternoon emergency medical services (EMS) flight in England and had been landed on a road to pick up a traffic-accident victim and to transport the victim to a nearby hospital. Before landing the helicopter, the pilot had maneuvered between two small trees on the north side of the road and had conducted a vertical descent.

About 30 minutes later, after the victim had been placed in the helicopter, the pilot conducted a takeoff by raising the helicopter into a high hover and moving the helicopter backward slowly above the road.

The accident report said, "Guided by a crewman looking out of the open port [left] door, he continued until the aircraft was above the two small trees he had passed between [while] landing, and then he started to maneuver north back into the clear area. In moving backwards, the helicopter was not very close to a large tree on the southern side of the road. On starting to move towards the clearing, the main rotors struck a branch in the tree."

The pilot landed the helicopter on the road to assess the damage. The patient was removed from the helicopter, and after minor repairs at the site, the helicopter was flown to its base with only the pilot on board.

The pilot said that he had lost spatial awareness while the helicopter was on the road with the engines running. He said that, although he was aware of the large tree, he was not aware of a large branch of the tree behind the helicopter. Crewmembers were unable to see the branches on the trees to the south.

The pilot also said that he subconsciously conducted a helipad vertical takeoff (which involves moving the helicopter rearward with the departure site in view while conducting a climb to a safe height to transition to forward flight) rather than lifting the helicopter into a high hover.

Flat-light Conditions Blamed For Pilot Disorientation

Hughes 369E. Substantial damage. No injuries.

Visual meteorological conditions prevailed for the midday aerial-surveying flight in the United States. The pilot said that he was flying the helicopter at a low altitude and hovering the helicopter about every 800 feet (244 meters) along the ground to allow crewmembers to drop stakes to mark a property boundary.

The pilot said that sky conditions varied from clear to overcast throughout the flight. He said that the helicopter struck the ground after he became disoriented and had difficulty discerning the horizon because of flat-light conditions in which the snow-covered ground appeared to blend with the overcast sky.

Blowing Dust Impairs Pilot's Vision During Landing

Eurocopter AS 350B2. Minor damage. No injuries.

Visual meteorological conditions prevailed for the late-morning landing in a confined area on a farm in South Africa.

As the pilot conducted the landing, downwash from the main rotor blew red dust from the ground into the air, impairing the pilot's vision. The incident report said that the pilot "allowed the helicopter to move forward while he was temporarily blinded by the dust … and allowed the main-rotor blades to make contact with a tree."♦

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