Flight Safety DIGEST

MAY 2005

See What's Sharing Your Airspace

Flight Safety Foundation

For Everyone Concerned With the Safety of Flight

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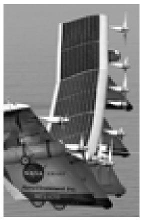

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See What's Sharing Your Airspace

Trans-Pacific flights by a nearly 26,000-pound gross weight U.S. Air Force Global Hawk unmanned aerial vehicle (UAV) helped drive the current quest for commercial applications. Flying UAVs in civil airspace demands solutions to problems such as collision avoidance and failure of data/communication links with a ground-based pilot thousands of miles from the aircraft.

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2004 Was 'Safest Year Ever' For Air Transport

Despite an increase in passenger traffic, there were fewer fatalities worldwide in 2004 involving large Western-built commercial jets than in each of the previous two years. The number of accidents and the rates of accidents declined for air carriers flying under U.S. Federal Aviation Regulations Part 121, and there were no fatal accidents for scheduled flights under Part 135.

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'Root Causes' in the System Can Underlie Human Error

Operational human error in accidents is often only the final manifestation of 'latent' human error in management, design and maintenance. An open organizational culture and user-centered design are said to be among the ways to minimize human error.

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Severe Vibration Accompanies Braking During Landing Rollout

After the landing at an airport in Wales, ground personnel found what appeared to be brake parts on the runway.

Cover photo: The AeroVironment Helios Prototype flew to nearly 97,000 feet in August 2001 in flight tests by the U.S. National Aeronautics and Space Administration (NASA). With a wingspan of 256 feet (78 meters), solar panels, fuel cells and 10 electric motors, it flew partly "to develop technologies to enable unmanned aerial vehicles (UAVs) to perform a variety of long-duration missions, including environmental monitoring and telecommunications-relay services," NASA said. This UAV experienced control difficulties at about 3,000 feet during its 10th flight in a restricted area near the Hawaiian island of Kauai, struck the Pacific Ocean and was destroyed on June 26, 2003. A similar UAV, Pathfinder-Plus (see page 22), continues to be flown for NASA research. (Photo: Carla Thomas, NASA)

See What's Sharing Your Airspace

Trans-Pacific flights by a nearly 26,000-pound gross weight U.S. Air Force Global Hawk unmanned aerial vehicle (UAV) helped drive the current quest for commercial applications. Flying UAVs in civil airspace demands solutions to problems such as collision avoidance and failure of data/communication links with a ground-based pilot thousands of miles from the aircraft.

— FSF EDITORIAL STAFF

The General Atomics Aeronautical Systems Altair can fly at 52,000 feet and remain airborne for more than 30 hours. The aircraft's uses include nautical charting, fisheries assessment and climate research. (Photo: Tom Tschida, NASA)

Technological advances, military-industrial initiatives and fast-track regulatory activities are on the verge of launching a new era of routine flight by unmanned aerial vehicles (UAVs) in civil airspace. Often defined as "aircraft designed to operate with no human pilot aboard,"[1] UAVs also are called uninhabited air vehicles, remotely operated aircraft and other terms. For example, the U.S. Federal Aviation Administration (FAA) and the U.S. Department of Defense (DOD) have begun to replace "UAV" with "unmanned aircraft system" as their preferred term.[2] Public interest in UAVs has intensified as news media cover military operations in Afghanistan and Iraq. Large UAVs routinely are flown over these countries and controlled via satellite data link by a ground-based pilot situated in a ground control station in California, U.S.[3] The typical remote-control system comprises the UAV, ground control station, control data link that operates at line-of-sight distances and/or over-the-horizon distances, and data/voice radio relay.

"UAVs will range in size from several ounces to thousands of pounds," said a 2004 MITRE Corp. report for FAA. "Many will fly slowly and lack

"Who would have dreamt 20 years ago … that the product you purchased over the Internet would arrive one day on a UAV?"

maneuverability, whereas others will operate at very high speeds with great agility. … Further, the types of missions being planned for UAVs of the future are rarely point-to-point but typically involve some form of patterned flight or tracking activity that may include intermittent short-[term orbits] or long-term orbits."[4]

The ground-based pilot's location in a ground control station causes significant limitations compared with pilots of manned aircraft.

"Rather than receiving direct sensory input from the environment in which his/her vehicle is operating, a [ground-based pilot] receives only that sensory information provided by on-board sensors via data link," said aerospace researchers at the University of Illinois, U.S. "Currently, this consists primarily of visual imagery covering a restricted field of view. Sensory cues that are lost therefore include ambient visual information, kinesthetic/vestibular input and sound. … [A ground-based pilot] can be said to perform in relative 'sensory isolation' from the vehicle under his/her control. … To the [ground-based pilot] of a UAV with a conventional display, turbulence is indicated solely by perturbations of the camera image provided by the UAV sensors."[5]

Integration of military/government UAVs and commercial UAVs into civil airspace may occur sooner than many aviation professionals anticipate, based on the highly touted suitability of UAVs for dull, dirty and/or dangerous missions (i.e., flights that exceed human physical/mental stamina or subject pilots to environmental hazards or significant safety/security threats).

Moreover, FAA Administrator Marion Blakey said in March 2005, "[Forecasts of air traffic] present some enormous challenges and risks. And to a person here, we fully recognize that the current system cannot accommodate such huge new demand. It was never designed to handle the projected new mix of air traffic in our skies. … In 2025, we could be looking at three times more passengers, operations and cargo than we had in 2000 [in the United States]. We need a system that can accommodate anything our imagination and entrepreneurs can serve up. Who would have dreamt 20 years ago that hailing a taxi could mean calling a very light jet? Or that the product you purchased over the Internet would arrive one day on a UAV? Twenty years ago, we called people like that dreamers. Today, they're called investors."[6]

As of early 2004, more than 40 countries operated more than 80 types of UAVs, said the report of a European UAV task force. The performance of current UAVs varies widely in speed, altitude, mission duration and payload capability.[7]

"To date, approximately 90-plus percent of all funding for UAV systems is a direct result of national government requirements channeled through their military and defense program elements," the European task force report said. "The primary mission profiles are quite similar both on the military [side] and civil side; [they] are mainly earth observation … and communications."

Most large UAVs currently being flown in U.S. airspace carry radio-relay equipment that enables ground-based pilot–air traffic control (ATC) voice communication to be conducted much as if the pilot were aboard an aircraft. This simplifies communication and provides pilots of aircraft near a UAV with a method of situational awareness. Equipping small UAVs with radio-relay equipment for ATC communication often is not possible because of payload limitations.[8]

"UAVs offer a unique range of features, most notably ultra-long endurance and high-risk mission acceptance, which cannot be reasonably performed by manned aircraft," said the MITRE report. "These features — when coupled with advances in automation and sensor technologies, and the potential for cost savings — make a strong case for the eventual emergence of a robust civil, government and commercial UAV market."

Some Divide UAVs Into Three Basic Categories

The UAV community and civil aviation authorities envision gradual integration of different categories of UAVs into civil airspace. Table 1 (page 3) shows the performance specifications of several

Continued on page 5

Table 1

Performance Specifications of Unmanned Aerial Vehicles, by Gross Weight

UAV Category and Name	Manufacturer, First Flight and Cost[1]	Gross Weight	Dimensions and Payload[2]	Operating Parameters[2]	Propulsion, Control and Endurance[3]
RQ-4A Global Hawk	Northrop Grumman Corp.; 1998; US$20 million	25,600 pounds (11,612 kilograms)	Wingspan 116.2 feet (35.4 meters); length 44.3 feet (13.5 meters); payload 2,000 pounds (907 kilograms)	345 knots; 13,500 nautical miles; more than 65,000 feet	Single turbofan engine; autonomous; 36 hours endurance
Proteus	Scaled Composites; 1998	12,500 pounds (5,670 kilograms) in nonmilitary uses	Wingspan 92.0 feet (28.0 meters); length 56.3 feet (17.2 meters); height 17.6 feet (5.4 meters) on landing gear; 2,000 pounds (907 kilograms); payload 1,800 pounds to 7,260 pounds (816.5 kilograms to 3,293.1 kilograms)	280 knots at 40,000 feet; 65,000 feet at 7,000 pounds (3,175.1 kilograms); 58,000 feet at 12,500 pounds; optionally manned by one pilot	Two turbofan engines; autonomous/remotely operated/onboard pilot; 18 hours endurance
X-45A	The Boeing Co.; 2002	11,000 pounds (4,990 kilograms)	length 27 feet (8.2 meters); 3,000 pounds (1,361 kilograms)	Mach 0.75 (approximately 496 knots); 450 nautical miles (833 kilometers) radius of action with 30-minute loiter; more than 35,000 feet	Single turbofan; autonomous
MQ-9 Predator B	General Atomics Aeronautical Systems; 2001; $8.7 million	10,000 pounds (4,536 kilograms)	Wingspan 64.0 feet (19.5 meters); length 36.2 feet (11.0 meters); internal payload 750 pounds (340 kilograms); external payload 3,000 pounds (1,361 kilograms)	220 knots; 400 nautical miles (741 kilometers) radius of action; 45,000 feet	Single turboprop; autonomous; more than 24 hours endurance
Altair (variant of MQ-9 Predator B)	General Atomics Aeronautical Systems; 2003; $8 million	7,000 pounds (3,175 kilograms)	Wingspan 86.0 feet (26.2 meters); length 36.0 feet (11 meters); internal payload 660 pounds (300 kilograms); external payload 3,000 pounds (1,361 kilograms)	210 knots at 52,000 feet	Single turboprop engine or turbofan engine; triplex redundant flight-control system; radio link; satellite communications link; autonomous; more than 30 hours endurance
RQ-6 Fire Scout (VTOL)	Northrop Grumman Corp.; 1999	2,550 pounds (1,157 kilograms)	Main-rotor diameter 27.5 feet (8.4 meters); length 22.9 feet (7.0 meters) folded; height 9.4 feet (2.9 meters)	More than 125 knots; 110 nautical miles (204 kilometers) radius of action; 20,000 feet	Single turbine engine and main rotor; autonomous; more than six hours endurance
MQ-1 Predator	General Atomics Aeronautical Systems; 1994; $2.4 million	2,250 pounds (1,021 kilograms)	Wingspan 48.7 feet (14.8 meters); length 27 feet (8.2 meters); payload 450 pounds (204 kilograms)	70 knots; 400 nautical miles (741 kilometers) radius of action; 25,000 feet	Single turboprop; autonomous; more than 24 hours endurance

Table 1
Performance Specifications of Unmanned Aerial Vehicles by Gross Weight (continued)

UAV Category and Name	Manufacturer, First Flight and Cost[1]	Gross Weight	Dimensions and Payload[2]	Operating Parameters[2]	Propulsion, Control and Endurance[3]
Perseus B	Aurora Flight Sciences; 1994	2,200 pounds (998 kilograms)	Wingspan 71.5 feet (21.8 meters); length 25 feet (7.6 meters); height 12 feet (3.7 meters); payload 264 pounds (120 kilograms)	52 knots; 1,600 nautical miles (2,963 kilometers) point-to-point; 60 nautical miles (111 kilometers) radius of action; 62,000 feet	Single reciprocating engine and propeller; remotely operated (includes flight termination system with parachute); 24 hours endurance
RQ-5 Hunter	Israel Aircraft Industries/Malat and Northrop Grumman Corp.; 1990; $1.2 million	1,600 pounds (726 kilograms)	Wingspan 29.2 feet (8.9 meters); length 23.0 feet (7.0 meters); payload 200.0 pounds (90.7 kilograms)	100 knots; 144 nautical miles (267 kilometers) radius of action; 15,000 feet	Two reciprocating gasoline engines and propellers; autonomous; 11.6 hours endurance
Pathfinder-Plus	AeroVironment; 1998	700.0 pounds (317.5 kilograms)	Wingspan 121.0 feet (36.9 meters); length 11.0 feet (3.4 meters); payload 700.0 pounds (317.5 kilograms)	Slow-flying ultralight; unspecified range; 82,000 feet	Eight solar-powered electric motors with propellers; remotely operated via satellite link; unspecified endurance
RQ-2 Pioneer	Israel Aircraft Industries/Pioneer UAVs; 1985	452 pounds (205 kilograms)	Wingspan 17.0 feet (5.2 meters); length 14 feet (4.3 meters); payload 75 pounds (34 kilograms)	80 knots; 100 nautical miles (185 kilometers) radius of action; 15,000 feet	Single reciprocating gasoline engine and propeller; autonomous; five hours endurance
RQ-7 Shadow 200	Israel Aircraft Industries; 1998; $325,000	327 pounds (148 kilograms)	Wingspan 12.8 feet (3.9 meters); length 11.2 feet (3.4 meters); payload 60.0 pounds (27.2 kilograms)	82 knots; 68 nautical miles (126 kilometers) radius of action; 15,000 feet; launched by catapult rail; recovered by arresting equipment	Single reciprocating engine and propeller; autonomous/remotely operated; four hours endurance
RMAX Type IIG (VTOL)	Yamaha Motor Co.; 2003	207 pounds (94 kilograms)	Main-rotor diameter 10.20 feet (3.12 meters); length 11.90 feet (3.63 meters); height 3.54 feet (1.08 meters); payload 61.7 pounds (28.0 kilograms)	11 knots for crop dusting; 492 feet (150 meters) typical distance from operator; 16.4 feet for crop dusting to 328 feet for aerial imagery	Reciprocating water-cooled gasoline engine; autonomous flight termination/return to takeoff point using GPS sensor and gyroscopic sensor; remotely operated by maneuver command and hover; one hour endurance
Bird Eye 500	Israel Aircraft Industries/Malat; 2004	77.2 pounds (35.0 kilograms)	Wingspan 6.6 feet (2.0 meters); length 5.2 feet (1.6 meters); payload 30 ounces (850 grams)	60 knots; area of 39 square miles (10,000 hectares); 1,000 feet	Single electric motor and propeller (hand launch or bungee-cord launch); autonomous with in-flight waypoint control; more than one hour endurance

Table 1

Performance Specifications of Unmanned Aerial Vehicles by Gross Weight (continued)

UAV Category and Name	Manufacturer, First Flight and Cost[1]	Gross Weight	Dimensions and Payload[2]	Operating Parameters[2]	Propulsion, Control and Endurance[3]
APV-3	RnR Products; 2003	50.0 pounds (22.7 kilograms)	Wingspan 12.0 feet (3.7 meters)	90 knots	Single reciprocating gasoline engine and propeller; autonomous/remotely operated; preprogrammed navigation and in-flight waypoints dynamically configurable; eight hours endurance at 45 knots
Aerosonde UAV	Aerosonde; 1998	33 pounds (15 kilograms)	11 pounds (5 kilograms)	81 knots; 23,000 feet	Gasoline engine; propeller; autonomous; 32 hours endurance
FQM-151 Pointer	AeroVironment; 1989	10 pounds (4.5 kilograms)	Wingspan 9.0 feet (2.7 meters)	Airspeed not specified; 3.0 nautical miles (5.6 kilometers) radius of action	One electric motor, battery and propeller; remotely operated; one hour endurance
Dragon Eye	AeroVironment; 2000; $40,000	4.5 pounds (2.0 kilograms)	Wingspan 3.8 feet (1.2 meters); length 2.4 feet (0.7 meter); payload 1.00 pound (0.45 kilogram)	35 knots; 2.5 nautical miles (4.6 kilometers) radius of action	Specification unavailable (launched by bungee cord); autonomous

UAV = Unmanned aerial vehicle   VTOL = Vertical takeoff and landing (rotary wing)   GPS = Global positioning system

1. UAV cost, if available, may not include all elements of the complete system, such as sensors and ground control station.
2. Data are not complete for all UAVs.
3. UAVs may be remotely operated (i.e., with flight-control inputs/commands by a ground-based pilot using a ground control station) or operated autonomously (i.e., with pre-programmed flights conducted by on-board computers and navigation systems); combinations of these flight modes also may be used. Data are not complete for all UAVs.

Source: U.S. National Aeronautics and Space Administration; U.S. Department of Defense; U.S. Government Accountability Office; manufacturers

UAVs, including those that might be among the first to be integrated into civil airspace. Universally accepted categories have not emerged, but many studies distinguish UAVs with the following characteristics, whether they have a military application or government/commercial application:

- Large UAVs are capable of operating at the highest altitudes, possibly with the heaviest payloads, longest endurance and/or highest airspeeds (such as the military RQ-4A Global Hawk UAV and MQ-1 Predator UAV). For example, DOD and FAA have proposed to characterize large UAVs as capable of beyond-line-of-sight flight operations throughout all categories of civil airspace; compliant with U.S. Federal Aviation Regulations (FARs) Part 91 general operating requirements for manned aircraft (including sense-and-avoid capability); and requiring airworthiness certification and ground-based pilot certification;

- Medium UAVs comprise those capable of routinely conducting special-purpose flight operations with explicit flight restrictions (such as the military RQ-2 Pioneer UAV and RQ-7 Shadow 200 UAV); the maximum altitudes, airspeeds and payloads are similar to a small manned aircraft. DOD and FAA have proposed to characterize medium UAVs as restricted in access to civil airspace and requiring acceptable evidence of airworthiness and ground-based pilot qualification other than a pilot certificate;

- Small/light UAVs — similar to radio-controlled model aircraft — comprise those designed for operation at altitudes up to a few hundred feet at airspeeds much slower than small manned aircraft while carrying a payload such as a video camera, environmental sensors and transmitter (such as the military FQM-151 Pointer UAV and Dragon Eye UAV). DOD and FAA have proposed to characterize small/light UAVs as generally limited to line-of-sight operations, with the operator providing acceptable evidence of airworthiness and ground-based pilot/user qualification other than a pilot certificate. National regulations typically differentiate between a small/light UAV and a model aircraft based on criteria such as aircraft weight and/or its use for commercial purposes.[9]

Recent examples of the state of UAV technology include the following:

- One ground-based pilot simultaneously commanded flights by two turbofan-powered Boeing X-45A UAVs in flight formations in 2004, and accurately controlled the time of arrival for multiple-UAV flights over specified geographic locations;[10]
- During March 2002 flight tests near Las Cruces, New Mexico, U.S., a Proteus aircraft with a safety pilot aboard was flown by a ground-based pilot while several "cooperative" aircraft with operating transponders approached the Proteus from various angles. The cooperative aircraft maneuvered individually and in converging groups of two, and included a U.S. National Aeronautics and Space Administration (NASA) F/A-18 Hornet jet. In 18 simulated-conflict scenarios, sensors — combining a radio-based traffic-advisory system and infrared/radar technology — detected the collision threats and transmitted traffic advisories to the ground-based pilot, who altered the flight path in time for collision avoidance in all scenarios;[11]
- In April 2003, the Proteus was flown by a ground-based pilot while several "noncooperative" aircraft without operating transponders — ranging from a glider to the NASA F/A-18 — approached from various angles for 20 simulated-conflict scenarios. "For this series, the [Proteus was] equipped with a 35-gigahertz radar system [designed] to detect any approaching aircraft on a potential collision course, regardless of whether the intruder [was] equipped with an operating transponder," NASA said. The ground-based

The military Boeing X-45A unmanned aerial vehicle is designed to fly at Mach 0.75 (approximately 496 knots) at 35,000 feet.

(Illustration: The Boeing Co.)

The Scaled Composites Proteus aircraft, right, and a NASA F/A-18 Hornet flew near Las Cruces, New Mexico, U.S., in 2002 during testing of collision-avoidance systems for unmanned aerial vehicles. (Photo: Tom Tschida, NASA)

pilot altered the UAV's flight path in response to data received from the on-board radar system, maintaining a minimum 500-foot (152-meter) distance from the intruder aircraft in all scenarios. "The detection ranges were a little less than we expected but varied greatly from about 2.5 [nautical miles] to 6.5 nautical miles [4.6 kilometers to 12.0 kilometers], based on the structure and radar cross-section of the target aircraft," NASA said;[12]

- In March 2005, two APV-3 UAVs flown along computer-generated flight paths demonstrated the ability, without ground-based pilot intervention, to search in a rectangular grid pattern above a simulated forest fire while simultaneously conducting synchronized flight maneuvers that avoided obstacles, NASA said;[13]

- News media reports said that UAVs were used by the defense ministry of India to help locate survivors in distress, direct helicopter rescue operations and manage recovery operations during the country's response to the December 2004 Indian Ocean tsunami.[14]

- Beginning in 2004, U.S. Army RQ-5 Hunter UAVs were used for reconnaissance flights by the U.S. Department of Homeland Security along the Arizona border with Mexico 90 miles (145 kilometers) southeast of Tucson, Arizona, U.S. The UAV manufacturer, Northrop Grumman Corp., said that the capabilities of these UAVs include "sustained autonomous flight, high-resolution day and nighttime visual and infrared sensors, integrated [global positioning system (GPS)]-location systems, and the ability to relay communication signals to border-patrol agents. … Individuals on the ground may be unaware of this law-enforcement activity because of the [UAV's inconspicuous] visual profile at altitude and its quiet engine."[15]

- A civilian UAV flight in the Netherlands was conducted by Israel Aircraft Industries/Malat in June 2004. The Bird Eye 500 UAV was flown

A ground-based pilot flies the Scaled Composites Proteus aircraft during collision-avoidance testing by NASA. (Photo: Tom Tschida, NASA)

in the civil airspace of urban Amsterdam "to demonstrate the system's silent operation, ability to operate in high winds and minimal [equipment/personnel] for operation." The manufacturer said, "The [ground-based pilot] conducted rail-track monitoring, vehicle tracking, waterway monitoring and other missions using a high-resolution color camera and flying autonomous dedicated flight patterns."[16]

- During a Canadian Forces Experimentation Centre test flight of a UAV over the Atlantic Ocean in July 2003, personnel in the ground control station observed a "dark slick" trailing behind a commercial cargo ship. The UAV was flown closer to obtain images of the ship, its name and the apparent pollution. The information was provided to Transport Canada for further investigation, said National Defence of Canada.[17]

- In Hawaii, U.S., NASA conducted two scientific-research UAV flights to obtain images of a coffee plantation in September 2002. The purpose of the images was to measure field ripeness, map weeds and detect problems in fertilization and irrigation. The solar-powered Pathfinder-Plus UAV flew most of the mission in civil airspace.[18] During each flight, the UAV— equipped with an altitude-reporting transponder — initially climbed through Class D airspace, then through restricted airspace of a U.S. Navy facility to Flight Level (FL) 210 (approximately 21,000 feet), then entered airspace controlled by FAA air traffic controllers in Honolulu to operate over the plantation for four hours, then returned to the special use airspace and Class D airspace for descent and landing. "FL 210 was considered the optimal altitude from an ATC perspective, since the vast majority of [air carrier] aircraft operating in this same airspace are either at lower or much higher altitudes," said a report on the project. "Preplanned flight tracks were combined with spontaneous, controlled maneuvers to guide the UAV to cloud-free areas."

- The U.S. Air Force in August 2003 became the first U.S. organization to receive a national certificate of authorization (COA) from FAA for operation of the Global Hawk in U.S. airspace (called the National Airspace System), enabling FAA approval of flights to be granted in as few as five days compared with the normal minimum of 60 days. This process enabled this UAV to be operated in nearly all FAA ATC regions by conducting takeoffs, climbs, descents and landings in restricted areas and warning areas while conducting en route operations above the highest cruise altitudes used by air carrier aircraft. Some specialists call this flying through a "keyhole to the sky."[19] A U.S. Air Force Global Hawk also completed the first trans-Pacific flight by a UAV and the longest nonstop UAV flight in April 2001 during a deployment from California, U.S., to Australia and completed a return flight to the United States two months later;[20] and,

- Small helicopter-type UAVs were used in the United States for security-related surveillance of public events such as the 77th Academy Awards of the U.S. Academy of Motion Picture Arts and Sciences in Los Angeles, California.[21]

Japanese UAVs Stimulate Commercial Applications

The more than 2,000 helicopter-type UAVs used in growing rice, wheat and soybeans in Japan have set an important commercial example, many specialists said. One of the most widely used types — the Yamaha Motor Co. RMAX series — has been flown for observation of volcanic eruptions with an on-board video camera and video link. This type of UAV also has been flown for plant-growth observations, airborne-radiation detection and bridge inspections.

These agricultural UAVs typically are operated at altitudes of 10 feet to 16 feet and an airspeed of 11 knots. The portable ground control station allows the ground-based pilot to fly the UAV within a 200-meter (656-foot) line-of-sight distance. Most Japanese agricultural UAVs operate by line-of-sight data link at altitudes of less than 164 feet. For observation missions, some of these helicopter-type UAVs can operate autonomously — i.e., with programmed flights conducted by on-board computers and navigation systems — using beyond-the-horizon data links at altitudes up to 492 feet. Changes to Japanese civil aviation regulations will be required to routinely fly UAVs at higher altitudes in civil airspace.[22] Under the current system, more than 5,500 licensed ground-based pilots are available to operate the agricultural UAVs for application of liquid/granular crop insecticide across 500,000 acres [202,343 hectares] of agricultural land per year.[23]

In one agricultural test of UAVs in the United States, a NASA APV-3 was used in August 2003 and spring 2005 to obtain digital imagery of a 5,000-acre (2,023-hectare) vineyard near Monterey, California, to map differences in the vigor of grape plants and to test airborne frost-detection sensors. In another multi-year project begun in 2001, a NASA Altus II UAV with infrared sensors has been used to demonstrate methods of wildfire detection and tactical fire fighting.[24]

The MITRE report said that near-term uses of nonmilitary government UAVs also may include "emergency response; … search and rescue; forest-fire monitoring; communications relay; flood mapping; high-altitude imaging; nuclear-biological-chemical sensing/tracking; traffic monitoring; humanitarian aid; land-use mapping; and chemical and petroleum spill monitoring."[25]

Expected commercial applications for UAVs include "crop monitoring; … motion picture [production]; communications relay; utility inspection [pipelines/power lines]; multi-sensor station-keeping [maintaining a position in the sky]; news media support; aerial advertising; fish spotting; surveying and mapping; commercial imaging; cargo; and commercial security."[26] Although UAV commercial cargo flights often are envisioned, predicting when such flights might begin depends on many variables.

One U.S. air cargo company said, "Since its inception in 1986, UPS Airlines has maintained a primary goal: provide quality service to customers while operating in a safe and efficient manner. While this includes taking advantage of the latest technology, we don't see UAVs as part of our fleet in the near future."[27]

Scientific-research applications are creating many new markets, and NASA leases payload space/time on UAVs as large as the Altair to qualified research organizations, and has considered the Global Hawk. In one consultant's 2004 business model for NASA, the purchase price of an Altair was estimated to be US$8 million and associated

The Yamaha RMAX Type IIG — weighing 207 pounds (94 kilograms) with a main-rotor diameter of 10.2-feet (3.1 meters) — applies insecticides from 16 feet above crops in Japan while flying at 11 knots.

(Photo: Yamaha Motor Corp.)

The RnR Products APV-3 has an eight-hour endurance at 45 knots and a maximum cruise airspeed of 90 knots. Shannon Kolensky, a cooperative-program student, holds the aircraft during engine runup. (Photo: Tom Tschida, NASA)

ground equipment $6 million. The report said that U.S. Department of Homeland Security costs for Predator demonstration flights were $2,358 per flight hour for 106 flight hours in one 17-day series and $5,469 per flight hour for 128 flight hours in one five-day series, all in late 2003.[28] Worldwide, the nonmilitary uses of UAVs primarily have been in public-sector services, scientific research or aerospace research and development.

As an example of such scientific research, NASA and the U.S. National Oceanic and Atmospheric Administration (NOAA) in April and May 2005 conducted a series of Altair UAV flights off the coast of Southern California near the Channel Islands.[29]

"The goal … is to demonstrate the operational capabilities of [UAVs] for science missions related to oceanic and atmospheric research, climate research, marine-sanctuary mapping and enforcement, nautical charting, and fisheries assessment and enforcement," said Thomas J. Cassidy Jr., president and CEO of General Atomics Aeronautical Systems.

"UAVs will allow us to see weather before it happens, detect toxins before we breathe them and discover harmful and costly algal blooms before the fish do — and there is an urgency to more effectively address these issues," said Conrad C. Lautenbacher Jr., undersecretary of commerce for oceans and atmosphere, and NOAA administrator.

"NASA is glad to see that UAVs are being used for more and more diverse and important operations, and we're looking forward to routine access to [U.S. airspace] that will allow UAVs to play an expanding role in earth science and other types of missions," said Terrence Hertz, deputy associate administrator for technology, NASA Aeronautics Research Mission Directorate.

Other objectives include atmospheric sampling and imaging of the Channel Islands National Marine Sanctuary "to examine shorelines and evaluate the potential for marine enforcement surveillance."

Complex Impediments Drive Research on Many Fronts

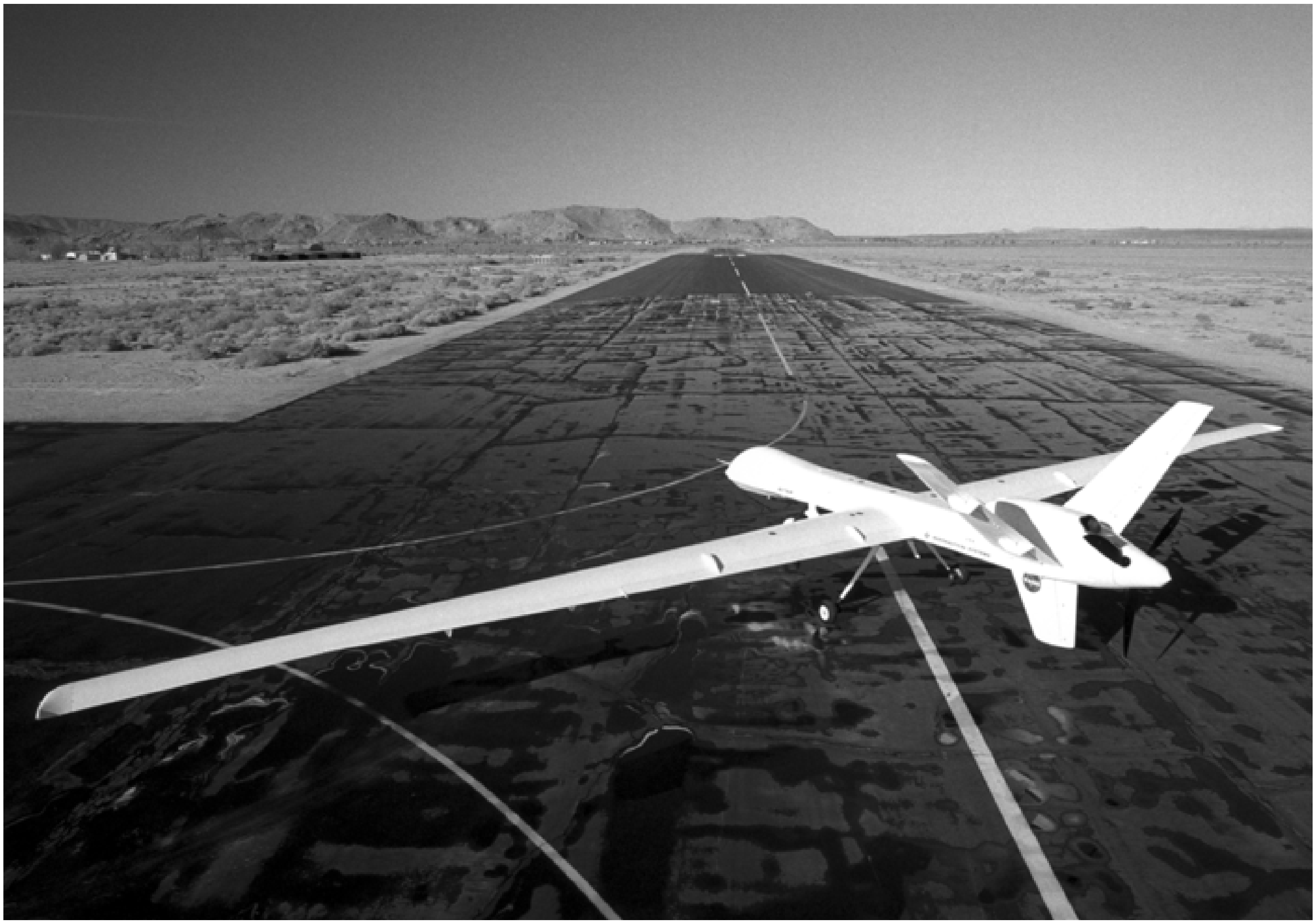
Integration of UAVs into civil airspace faces a number of challenges. The European UAV task force, for example, said that operators of UAVs may have difficulty complying with international rules for avoiding collisions; for detecting visual signals from ATC; for preventing unlawful interference with a UAV, data link or ground-control station; and for observation by the ground-based pilot of visual signals from the pilot of an intercepting aircraft.

Overall, recent studies point to the following requirements for large UAVs and medium UAVs to operate in civil airspace:

- On-board sense-and-avoid capability — independent of the data link to the ground-control station — to help prevent in-flight collision;
- On-board capability to autonomously prevent a collision with terrain or obstacles;
- Adequate UAV airworthiness and reliability;
- A method for autonomous flight continuation and termination by the UAV if failure occurs in the data link to the ground control station;
- A method for the UAV to comply with ATC instructions — such as direct commands to the UAV from an air traffic controller — if a failure occurs in communication between ATC and the ground-based pilot;
- A backup system for approach and landing if UAV navigation based on GPS fails;
- Mitigation of human factors risks in UAV operations, such as flight handovers between ground-based pilots, procedural errors or fatigue/boredom during flight monitoring; and,
- Mitigation of environmental risks to UAVs such as weather, bird strikes and turbulence.

Moreover, security of UAVs and ground control stations is essential because of the possibility that they could be used for hostile purposes, U.S. government reports said.

"UAVs represent an inexpensive means of launching chemical and biological attacks against the



Long, narrow wings of the General Atomics Aeronautical Systems (GA-ASI) Altair enable NASA to conduct 210-knot flights at 52,000 feet. (Photo: NASA – Alan Waide, GA-ASI)

A satellite antenna, electro-optical/infrared sensors and ocean-color sensors fill the payload bay of a General Atomics Aeronautical Systems Altair. The equipment was used to measure Pacific Ocean color, atmospheric conditions and temperatures for Al Gasiewski, a scientist with the U.S. National Oceanic and Atmospheric Administration.

(Photo: NOAA)

United States and allied forces and territory," said a 2004 report by the U.S. General Accounting Office (now Government Accountability Office). "The acting deputy assistant secretary of state for nonproliferation testified in June 2002 that UAVs are potential delivery systems for [weapons of mass destruction (WMD)], and are ideally suited for the delivery of chemical and biological weapons given their ability to disseminate aerosols in appropriate locations at appropriate altitudes. He added that, although the primary concern has been that nation-states would use UAVs to launch WMD attacks, there is potential for terrorist groups to produce or acquire small UAVs and use them for chemical or biological weapons delivery."[30]

Sense-and-avoid Capability Considered Indispensable

Sense-and-avoid capability refers to any technology or method that compensates for the absence of an on-board pilot who, regardless of the class of airspace or whether ATC provides separation services, would be required to see and avoid other aircraft whenever weather conditions permit.[31]

DOD defines sense-and-avoid capability as "the on-board, self-contained ability to detect traffic that may be a conflict, evaluate flight paths, determine traffic right-of-way, maneuver well clear according to the rules in FARs Part 91.113 ["Right-of-way Rules; Except Water Operations"] or maneuver as required in accordance with Part 91.111 ["Operating Near Other Aircraft]."[32] A conflict is defined as another aircraft that will pass less than 500 feet [152 meters], horizontally or vertically, from the UAV.[33]

Related FARs on aircraft airworthiness and scientific research suggest that sense-and-avoid capability should provide the ground-based pilot a minimum traffic-detection field of view of plus or minus 110 degrees in azimuth measured from the UAV's longitudinal axis and plus or minus 15 degrees in elevation from the [longitudinal axis during cruise flight]. (This elevation range would be consistent with research on timely detection of threats from climbing/descending aircraft.)[34]

In civil airspace where aircraft already are required to carry altitude-reporting transponders, UAV sense-and-avoid possibilities include TCAS II (which has not been certified for use on UAVs); ground-based secondary surveillance radars (such as the traffic information service [TIS] in the United States or FAA's proposed surveillance data network [SDN]); and automatic dependent surveillance–broadcast (ADS-B, assuming that the aircraft and UAVs carry this equipment in the future). Much of the research into sense-and-avoid methods for airspace where threat aircraft may not carry altitude-reporting transponders has focused on airborne primary radar, airborne passive infrared sensors, airborne passive visual sensors, ground-based primary radar (i.e., with horizontal threat data provided to ground-based pilots by ATC via landline communication) or combinations of these methods.[35]

In theory, routine authorization of UAV operations in civil airspace could be accomplished more readily in some airspace than other airspace, said a report by Massachusetts (U.S.) Institute of Technology (MIT) Lincoln Laboratory. MIT researchers currently are studying how TCAS II with resolution advisories could be employed on the Global Hawk.[36]

"A see-and-avoid capability is seldom needed in Class A airspace and, because of the high speeds typically found at these altitudes, the effectiveness of see-and-avoid is minimal," the report said. "The most challenging requirements for [UAV] see-and-avoid in Class E airspace occur below 10,000 feet, where VFR traffic is permitted to fly without transponders."

The researchers have considered the possibility that different methods of providing the required UAV safety level may be required in different airspace rather than the same methods for all airspace.

"[A UAV] that flies exclusively in Class A airspace would encounter only other IFR [instrument flight rules] traffic and would receive positive separation control by ATC," the report said. "It is possible that the necessary improvement in safety could be achieved merely by equipping such [a UAV] with a 25-foot altitude-reporting Mode S transponder, a reliable low-latency communication link between ATC and the [ground-based pilot], and a means of handling lost link and emergency (e.g., engine failure) operations. In this case, safety analysis need not await the definition of new surveillance and avoidance algorithms."

Problems in using current aircraft collision-avoidance technology for UAVs, however, include the differences in typical flight paths within a given type of airspace.

"Global Hawk, for example, flies at relatively low airspeed and high climb rate, resulting in a steeper climb profile than typically occurs with jet transports," said another MIT Lincoln Laboratory report. "As a result, encounters with Global Hawk may involve a higher rate of high-vertical-rate situations than is reflected in the existing encounter models [i.e., software models that can generate millions of air-traffic-encounter situations based on close encounters in actual air traffic radar data in specific airspace]."[37]

Nevertheless, other specialists have voiced concerns about the use of TCAS II for UAVs, primarily because UAVs do not fit original assumptions about how TCAS would be used.

"First, the current surveillance, display and algorithm designs of TCAS were developed and validated for aircraft with on-board pilots," one MIT Lincoln Laboratory report said. "[International Civil Aviation Organization (ICAO)] panels … have advised against using existing TCAS on [UAVs], citing in particular interactions with other aircraft carrying [airborne collision avoidance systems (ACAS)]. Additionally, [a working group of the ICAO panel] has stated that the ICAO mandate requiring TCAS on large piloted aircraft does not apply to [UAVs]. … A second concern is that TCAS was never intended to replace see-and-avoid. … Although pilots routinely monitor their TCAS traffic displays when flying in high-density airspace and depend upon them to verify the operating integrity of their TCAS equipment, the displayed information by itself is not adequate to support avoidance maneuvers."[38]

"Global Hawk … flies at relatively low airspeed and high climb rate, resulting in a steeper climb profile than typically occurs with jet transports."

The TCAS II design also assumes specific pilot-response times — five seconds in the ICAO TCAS standard — to a resolution advisory, but ground-based pilots would operate in an environment involving different response times.

"Response times for a [ground-based pilot] could differ both due to communication latency and to alternate control methods such as the use of a computer mouse

U.S. Air Force crewmembers at Beale Air Force Base, California, U.S., check their squadron's first Northrop Grumman RQ-4A Global Hawk, which can cruise at 345 knots at 65,000 feet.

(Photo: John Schwab, U.S. Air Force)

rather than a control yoke," said one report. "Remote control delays could decrease maneuver effectiveness and retard or negate TCAS–TCAS coordination. Lack of visual cues to check TCAS integrity or maneuver reasonableness could also increase collision risk." (Latency of the voice link between a ground-based pilot and ATC may be one second or more, and may increase the probability of mistimed responses to transmissions, possibly requiring a dedicated communication link for UAV flights in relatively congested airspace, the report said.)[39]

ICAO working groups have recommended that for the near future, UAVs carry 25-foot altitude-reporting Mode S transponders and not be equipped with TCAS II. "Mode S equipage would allow ground controllers [ATC] and TCAS-equipped aircraft to track the [UAV] with precision, and TCAS[-equipped aircraft] and other controlled aircraft could maneuver to avoid the [UAV]," a MIT Lincoln Laboratory report said.[40]

The U.K. Civil Aviation Authority (CAA) in 2004 said that current technology and research have not yet enabled U.K. regulators to specify an acceptable sense-and-avoid capability for UAVs.

U.K. CAA said, "The CAA policy on UAV sense-and-avoid criteria is as follows: The overriding principle when assessing if a proposed UAV sense-and-avoid criterion is acceptable is that it should not introduce a greater hazard than currently exists. … From these discussions [with UAV-community representatives] and its own deliberations, the CAA has concluded that the full range of parameters which may have to be taken into account in any solution of the sense-and-avoid problem has yet to be established. … Any agreed sense-and-avoid criteria must be acceptable to other existing airspace users."[41]

Similarly, a 2004 U.S. Air Force report said, "At this point in the development of [a sense-and-avoid] system, we do not have all the information necessary to establish a defensible and tangible value for [equivalent level of safety comparable to manned aircraft]."[42]

Regarding UAV navigation, a DOD report said that current GPS-based systems generally meet standards for military operations without redundancy and without reliance on ground-based navigation aids.

"However, UAVs have a diminished prospect for relief since, unlike [the pilot of a] manned aircraft, a [ground-based pilot] cannot readily fall back on dead reckoning, contact navigation and map reading in the same sense that a manned-aircraft [pilot can use these backup methods]," the report said.[43]

Therefore, the absence of an on-board pilot changes the nature of the risk of the UAV colliding in flight with another aircraft, another UAV or birds, or striking terrain, water, obstacles or people on the ground. Both scenarios have been computer-simulated for UAVs in various studies.

Visual Methods Aim to Prevent Midair Collisions

Making UAVs visually conspicuous to the pilots of manned aircraft and to other UAVs will require a variety of methods to complement sense-and-avoid capability. The European UAV task force said that, subject to further research, this may be a reason to require UAVs to display anti-collision lights and navigation lights 24 hours a day.

"For [crews of] manned aircraft, avoiding collisions with UAVs may yield additional complications," the task force said. "If a crew separates by see-and-avoid, it may misread the distance to a UAV if its size differs significantly from that of a similarly shaped manned aircraft. [This may occur only] if the crew can distinguish that it is a UAV at all. Such UAVs shall be visually distinguishable from manned aircraft, from any aspect angle. It may not be possible to achieve this by distinctive color schemes [which] may not be visible from all angles) or [by] distinctive lighting (the UAV may be too small to carry additional battery power). A UAV may need a method of indicating to a manned aircraft close by that the UAV is aware of the presence of the other aircraft (and taking appropriate action)."

Autonomous flight continuation/termination after failure of a UAV's data link to the ground control station could involve several methods, based on military UAV practices.

"In the event of lost command and control, military UAVs are typically programmed to climb to a predefined altitude to attempt to reestablish contact," said a DOD report. "If contact is not reestablished in a given time, the UAV can be preprogrammed to retrace its outbound route home, fly direct to home or continue its mission. With respect to lost communications between the ground control stations and the UAV, or the UAV and ATC, however, there is no procedure for a communications-out recovery. … Remarkably, most lost-link situations bear a striking resemblance to [no-radio IFR operations], and UAVs would enhance their predictability by autonomously following [this] guidance. … [Nevertheless,] UAVs, even with an adequate sense-and-avoid system (autonomous) would enhance overall safety by continuing to fly IFR [after encountering visual meteorological conditions]."[44]

"Radio-frequency jamming and unintentional interference primarily increase the workload of [ground-based] pilots and air traffic controllers when aircraft carry backup systems," said the 2002 DOD UAV roadmap of broad plans. "For systems solely dependent on GPS, loss of service leaves UAVs to rely on [inertial-navigation] systems, none of which, in today's [military] UAVs, have drift rates allowing the successful completion of a sortie through to landing," DOD said.

RTCA Accepts Challenge of Setting UAV Standards

Among major efforts in the United States for accelerated integration of UAVs into civil airspace is RTCA Special Committee 203, Minimum Performance Standards for Unmanned Aircraft Systems and Unmanned Aircraft, which conducted its first meeting in December 2004. Members include representatives of government, military services, academia, manufacturers, an air traffic controller association, pilot unions and airlines. The committee initially is scheduled to develop minimum aviation system performance standards for UAVs by December 2005; command, control and communication systems for UAVs by June 2006; and sense-and-avoid systems for UAVs by December 2007. These products "will help assure the safe, efficient and compatible operation of [UAVs] with other vehicles

"The UAV can be preprogrammed to retrace its outbound route home, fly direct to home or continue its mission."

operating within [U.S. airspace]," RTCA said.

FAA said that two critical questions for this committee will be how to handle command and control of UAVs and how sense-and-avoid capability will be provided.

"With the standards we can make real progress … on the safe integration of [UAVs] into [U.S. airspace]," said Nick Sabatini, FAA associate administrator for regulation and certification. "We know demand is growing. There are many applications for [UAVs] and many who want to use them. This urgency is why we started the rulemaking [process]." An FAA notice of proposed rulemaking (NPRM) during 2005 will suggest a regulatory framework for how UAVs initially will be integrated; the notice primarily will address "[UAV] operation at lower altitudes using line-of-sight traffic deconfliction," he said.[45] The first FAR for UAVs also is expected to establish procedures for ground-based pilot letters of authorization and medical qualifications, and airworthiness certification of small/light UAVs, FAA said.[46]

The same infrastructure required for UAV integration into civil airspace … will have to be developed because of the traffic-volume increases of manned aircraft.

During the next 10 years, some specialists predict, the same infrastructure required for UAV integration into civil airspace — airborne traffic management to replace current ground-radar-based air traffic separation — will have to be developed because of the traffic-volume increases of manned aircraft.

"Sense-and-avoid [capability] will become an integrated, automated part of routine position reporting and navigation functions by relying on a combination of automatic dependent surveillance–broadcast (ADS-B) and [GPS]," said a joint report on UAV-integration plans by DOD and FAA. "In effect, it will create a virtual bubble of airspace around each aircraft so that when bubbles contact, avoidance is initiated. All aircraft will be required to be equipped to the same level, making the unmanned or manned status of an aircraft transparent to both flyers and to the FAA."[47]

Simulations Check Conformity To Target Safety Levels

A study of how to achieve acceptable target levels of safety for UAVs — measured as ground fatalities and fatalities from midair collisions — found that combinations of methods would be required for operators of some UAVs to bridge the gap between their estimated levels of safety and those already achieved by manned aircraft.[48]

To reduce the risk of ground fatalities caused by a UAV accident, various methods theoretically could achieve an acceptable level of safety and lessen the severity of a UAV ground impact, such as flight-termination systems and emergency parachute recovery systems, the report said.

When a UAV's location was assigned randomly in civil airspace with other air traffic, simulations showed that the level of safety would not meet the FAA target level of safety for midair collisions (one collision in 10 million hours of operation), the report said. To theoretically achieve this target level of safety in a specified air traffic density, various methods could be used, such as procedural separation of UAVs from high-density air routes, use of frangible UAVs (limiting impact damage to the scale of a bird strike), avoidance maneuvers by the UAV and operating the UAV above FL 450.

"It might be possible to significantly reduce the ambient risk of UAV operation by requiring the UAV to be operated away from airways and major flight levels," the report said. "[In the vicinity of jet routes] without mitigating action, there are few regions in the vicinity of airways with an expected level of safety below the target level of safety. … Significant mitigation would be required to operate higher-mass UAVs in [U.S. airspace]. … Under the assumptions of the analysis performed, high-altitude [large] UAVs pose a significantly greater risk than other [UAV] classes, and tactical [medium] UAVs represent an intermediate risk level. While the threat posed by higher-mass UAVs may be greater, they can also incorporate more sophisticated mitigation measures to prevent midair collisions, such as sense-and-avoid systems, or active air traffic control separation."[49]

Industry First Seeks High-altitude Access

Initiatives to integrate large UAVs — military, government and commercial — into civil airspace are in progress worldwide. For example, Access 5 — a long-term initiative involving high-altitude, long-endurance (HALE) UAVs in the United States — focuses on civilian UAVs capable of operation at 40,000 feet or higher for 24 continuous hours or more.[50] Access 5 is a project led by NASA to achieve routine operations by HALE remotely operated aircraft (UAVs) within U.S. airspace as soon as practical.

Because a series of ground-based pilots and/or support personnel can assume UAV flight control/monitoring duties without interrupting a multi-day UAV flight, one advantage of UAVs is that human performance theoretically could be consistent from the beginning of the flight to the end of the flight.[51]

NASA and the U.S. Department of Energy have demonstrated the use of sensors aboard HALE UAVs for remote agriculture monitoring, weather research and disaster monitoring (such as fires, floods, earthquakes/tsunamis and pollution events). Members of the Access 5 project cited several examples of anticipated commercial flights.

"In a nominal mission, the [UAV] would take off from [a UAV-]designated airport on an [IFR] flight clearance and climb to its cruising or mission altitude," the Access 5 report said. "The [UAV would] remain within or above controlled airspace for all operations. Throughout the flight, the link between the [UAV] and [ground] control station, and the link between the [ground-based pilot] and [ATC would] be maintained, both while the [UAV] is within line of sight and over the horizon from the control station. Also, since the [UAV always would] be under the command of a human [ground-based pilot], the links must be maintained regardless of the level of autonomy of the UAV. … The [UAV would] avoid adverse weather conditions throughout the flight.

"The [UAV also would] avoid conflicts with other air traffic through a combination of flight planning, ATC control and collision-avoidance technology. [UAV] navigation during the flight [would] be through a combination of on-board and off-board (control station) guidance. Mission-specific orbits or other deviations will be coordinated with ATC, and [either] preprogrammed, or directed from the control station. Any abnormal or 'emergency' operations [would] follow pre-established (with ATC) procedures, or coordinated with ATC in real-time, to divert to [a UAV-capable] airport or otherwise execute actions to minimize the risk to other [U.S. airspace] users, or people/property on the ground. Approach and landing [would] be to [a UAV-designated] airport using appropriate instrument arrival and approach/landing procedures."

The Access 5 concept of operations said that such a UAV might maintain position above a metropolitan area to provide telecommunications services similar to a satellite, with takeoff and landing conducted from the same airport and a line-of-sight data link to the ground control station. In another scenario, the UAV would transport cargo from a UAV-designated airport on one side of the United States to a UAV-designated airport on the opposite side.

Proponents of civilian HALE UAVs said that the pilot-certification requirements for operating a manned aircraft above FL 180 should apply to the ground-based pilots of these UAVs in Class A airspace and any other category of airspace.

Access 5 said that the following similarities and differences — compared with other aircraft — are anticipated:

- "[Ground-based pilots] will comply with airport procedures and follow standard operating procedures to the maximum extent possible or obtain waivers for any exceptions. … When [these UAVs] are unable to taxi to the active runway and have to be towed, procedures also must be publicized to the other airport users;
- "[In the en route phase, ground-based pilots] will maintain contact with the air route traffic control

The UAV would transport cargo from a UAV-designated airport on one side of the United States to a UAV-designated airport on the opposite side.

center [and] will use existing route structure to the maximum extent possible. If deviations are required, they will be coordinated with ATC;

- "[Ground-based pilots] will follow existing IFR departure, arrival and approach procedures [and radar approach control facilities/services] to the maximum extent possible. … If [the ground-based pilots] are unable to navigate along the IFR departure and arrival routes designed for manned aircraft, specific routes may need to be developed. … In some situations, the time of takeoff and arrival may be restricted to specific times when manned-aircraft operations are minimal; [and,]

- "Due to the nature of the [UAV] mission, it may be critical that the mission portion of the flight [be] given some priority for remaining on the [flight] profile unless safety [of] another aircraft is a greater concern. In this event, safety considerations must take [precedence] over the mission objectives."

U.S. Military Pursues 'File-and-fly' Simplicity

In the United States, an intense effort is underway to enable military ground-based pilots of large UAVs to file IFR flight plans with FAA and then operate routinely in civil airspace — to "file and fly" as soon as 2005 — with access to U.S. airspace equivalent to their counterparts flying manned aircraft.

"Military UAVs have historically been flown in restricted airspace (over test and training ranges) or war zones, and have thus largely avoided coming into conflict with manned civilian aircraft," said a 2004 DOD report. "This is changing. … Since the Sept. 11, 2001, terrorist attacks, airspace security has become an equal priority with safety, and the operation of military UAVs for homeland defense in [U.S. airspace] outside of restricted airspace increasingly is being considered."[52]

Under the current system, U.S. military UAV missions involving flights outside restricted areas and warning areas are accommodated by FAA on a case-by-case basis.

"Statutory language within the [U.S.] Code of Federal Regulations does not preclude military UAV flights in [U.S. airspace]," a DOD report said. "Rather, the limitations for military UAV flight are imposed by the [military] services due to the lack of appropriate equipage of these aircraft."[53]

Current UAV Operations Set Stage for Airspace Access

The requirements of military missions, government services, scientific research and commercial ventures intermittently have introduced UAVs to civil airspace in some countries. Typically, this temporary access is restricted, keeping UAVs separated much as aircraft are separated from a space vehicle during launch or landing/recovery.

Typically, regional FAA officials approve/deny COA applications on a case-by-case basis, and they use the notice to airmen (NOTAM) system to designate temporarily areas of civil airspace where the UAV will be authorized to fly or otherwise to separate UAVs and aircraft. The COA sets unique requirements for each flight — such as requiring airborne monitoring of the UAV from a chase aircraft.

Other methods of UAV–aircraft traffic separation also are used in the United States. In Alaska, NOTAMs are published and flight corridors are depicted on aeronautical charts showing low-altitude routes used routinely for line-of-sight VFR flights between military bases by ground-based pilots of small military UAVs.

NOTAMs are used by civil aviation authorities worldwide to advise civilian pilots how to avoid airspace conflicts with UAVs.

The following example of increasingly common UAV NOTAMs was published by Airservices Australia on April 25, 2005: "A small, unmanned aerial vehicle (UAV) will be operating within 1,500 meters [4,921 feet] of the aerodrome reference point. The operator will advise Brisbane Centre on 121.2 10 minutes prior to launch and on completion of each sortie. During operations, a listening watch will be maintained on the common traffic advisory frequency and Brisbane Centre 121.2 frequency. Broadcasts will be made on the common air traffic advisory frequency every 15 minutes. The unmanned aerial vehicle is a fixed-wing aircraft with a 4.1-meter [13.5-foot] wingspan and may be either gray or red in color. A ground control station will be established northeast of the intersection of Runway 05/23 and Runway 16/34. … The unmanned aerial vehicle controller [ground-based pilot] will maintain separation with other aircraft from the surface to 1,000 feet above ground level … in visual meteorological conditions for periods of up to 30 minutes."[54]

Safety Requires Consistent Accident/Incident Reporting

Aviation safety researchers in Europe and the United States have found UAV accident/incident data and UAV-reliability data to be sparse — except for data supplied by military sources. Some of these data are withheld from public use because they contain classified military information. Moreover, DOD reports on UAV accidents, incidents and reliability said that military data-collection methods have been inconsistent compared with methods of investigating, analyzing and documenting manned-aircraft mishaps.[55] Some DOD reports have called for improvements in safety/reliability data consistency and data analysis to improve UAV safety.

In general, mishaps involving military UAVs provide the only insights into safety lessons relevant to all UAVs. Studies of such data by DOD, FAA and the Government Accountability Office have included the following findings:

- One study calculated that from 1986 through 2001, rates of Class A[56] mishaps per 100,000 flight hours for DOD's predominant UAV systems were 32 for the Predator UAV, 334 for the Pioneer UAV and 55 for the Hunter UAV. These three types of DOD UAVs accumulated a combined total of 100,000 flight hours between 1986 and 2002 (i.e., mishap rates were interpolated because none of these types had accumulated 100,000 flight hours). "In comparison to manned [civilian] aviation mishap rates, general aviation aircraft suffer about one Class A mishap per 100,000 hours, regional/commuter airliners about a tenth of that rate, and larger airliners about a hundredth of that rate," the report said.[57]

- In 2002, a DOD goal was: "Decrease the annual mishap rate of larger-model UAVs to less than 20 per 100,000 flight hours by fiscal year

The Hunter II is designed for 30-hour missions up to 28,000 feet and is based on Northrop Grumman's earlier RQ-5 UAV Hunter aircraft, which have logged more than 32,000 flight hours.

(Photo: Northrop Grumman Integrated Systems)

2009 and [to] less than 15 per 100,000 flight hours by fiscal year 2015."[58]

- Data for the Global Hawk from February 1998 through August 2001 showed that four mishaps occurred with three of the UAVs destroyed. DOD said that the cause of a March 1999 mishap was an inadvertent radio transmission on the UAV's flight-termination frequency while it was airborne; the transmission was attributed to human error. The cause of a December 1999 mishap was a flight-control software error, which caused the UAV to accelerate off the end of a taxiway, damaging its nose and sensors. The cause of a December 2001 mishap was the failure of an incorrectly installed bolt in the ruddervator. The cause of a July 2002 mishap was a fuel-nozzle problem.[59]

"The proportions of human error-induced mishaps are nearly reversed between UAVs and the aggregate of manned aircraft, i.e., human error is the primary cause of roughly 85 percent of manned mishaps, but only 17 percent of [UAV mishaps]," said a DOD report about UAV reliability."[60]

Among efforts to understand human factors in military UAV mishaps and to apply lessons learned to civilian UAV operations, the FAA Civil Aerospace Medical Institute (CAMI) in 2004 found human factors issues involved in 21 percent to 68 percent of military UAV mishaps based on limited data provided by the U.S. military services.[61] The causal factors other than human factors issues also were categorized by CAMI researchers as maintenance-related, UAV-related or unknown without other details; for some types, failures of a tactical automated landing system (which controls the UAV during approach and landing, usually without ground-based pilot intervention) also were cited.

"Each of the fielded … systems is very different, leading to different kinds of accidents and different human factors issues."

"One critical finding … is that each of the fielded [DOD UAV] systems is very different, leading to different kinds of accidents and different human factors issues," the CAMI report said. "A second finding is that many of the accidents that have occurred could have been anticipated through an analysis of the user interfaces employed and procedures implemented for their use. For most of the [UAV] systems, electromechanical failure was more of a causal factor than human error. … Mishaps attributed at least partially to aircraft failures range from 33 percent [U.S. Air Force Global Hawk] to 67 percent [U.S. Army Shadow] in the data reported here."

After studying the operation of various military UAVs, CAMI researchers identified the following human factors issues:

- Control difficulty while ground-based pilots operated UAVs by visual contact — especially during takeoff and landing — which varied based on whether the UAV was flying toward the pilot or away from the pilot (i.e., spatial disorientation);

- Problems involving the authority of the ground-based pilot being superseded by the authority of other personnel involved in the flight, or problems in control handover;

- Failure of other personnel to communicate non-normal flight conditions and UAV conditions to the ground-based pilot;

- Absence of visual confirmation of autopilot status to the ground-based pilot except for a toggle-switch position;

- Absence of visual confirmation to the ground-based pilot of transmission of an engine-shutdown command, leading to engine shutdown on the wrong UAV;

- Errors in conducting checklists, resulting in inadvertent engine shutdown and in-flight shutdown of a flight-stability-augmentation system;

- Errors in following standard operating procedures for UAV operation and navigation;

- Weather-related decision-making errors during UAV flights;

- Inadvertent erasure by the ground-based pilot of the contents of random-access memory inside systems aboard the UAV; and,

- Excessive complexity in an automated mission-planning process, reducing situation awareness and ability to interpret status reports. This resulted in one incident, for example, of inadvertent programming of a UAV taxi speed of 155 knots without the knowledge of the ground-based pilot.

Overall, CAMI researchers found that the interface between the military ground-based pilot and hardware/software of the ground control station often was inconsistent with accepted aviation principles.

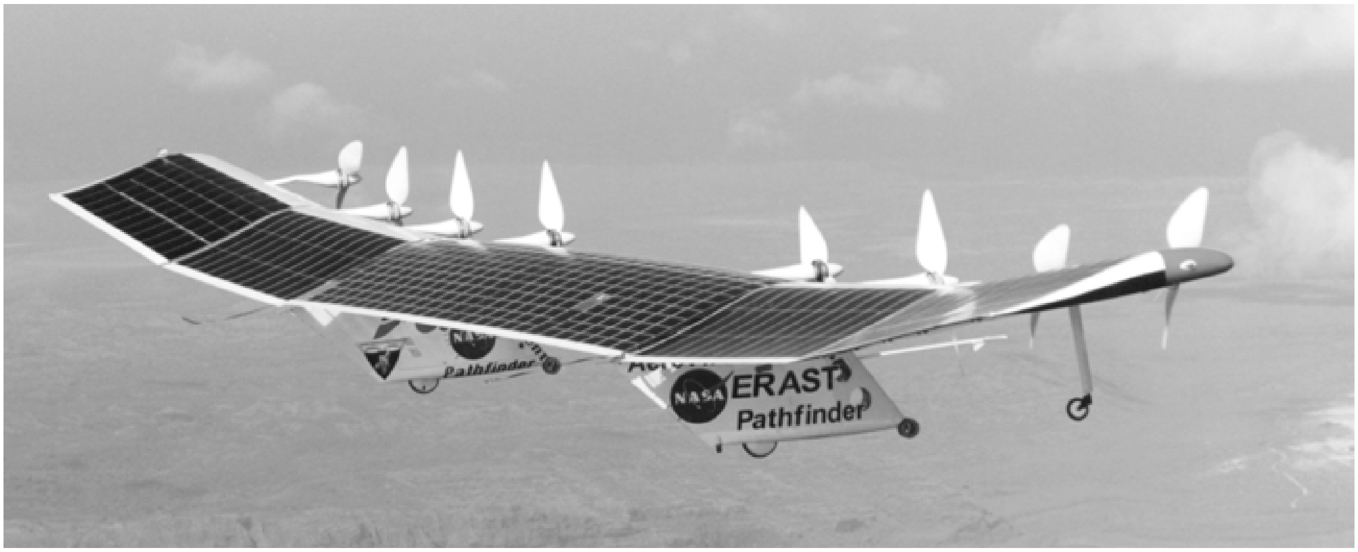
"The design of the user interfaces of [military UAV] systems are, for the most part, not based on previously established aviation display concepts," the CAMI report said. "Part of the cause for this is that the developers of these system interfaces are not primarily aircraft manufacturers. Another reason is that [some UAVs] are not 'flown' in the traditional sense of the word. Only one of the [UAVs] reviewed — Predator — has a [ground-based pilot] interface that could be considered similar to a manned aircraft. For the other [UAVs], control of the aircraft by the [ground-based pilot] is accomplished indirectly through the use of menu selections, dedicated knobs or preprogrammed routes. These aircraft are not flown but 'commanded.'"

One predictable source of human factors errors during UAV flights might be ATC.

"Because so few UAVs have interacted with the air traffic system to date, it is difficult to predict their impacts," said the MITRE report. "Controller roles may also be affected by UAV operations, though, in instances where controllers have handled UAVs to date, the procedures and communications were transparent; most [controllers were] not aware

A Northrop Grumman RQ-4A Global Hawk can fly 3,000 nautical miles (5,556 kilometers), remain on station for 24 hours and return to its departure point during one flight.

(Photo: Northrop Grumman Integrated Systems)



The AeroVironment Pathfinder-Plus, which preceded the AeroVironment Helios Prototype, has been flown to 82,000 feet. These UAVs have been used to demonstrate the use of solar-powered aircraft as high-altitude components in a telecommunications system. (Photo: Nick Galante, NASA)

they were controlling a UAV. This has at least been the case with the larger, sophisticated UAVs that operate within manned-aircraft performance parameters; however, this may not be the case for other UAVs that are typically slower, cannot perform standard-rate turns at altitude, and may be unable to climb or descend at rates familiar to controllers."

Among ATC changes under consideration in the United States are methods of distinguishing UAVs in flight plans and radar displays, possibly indicating to ATC whether the ground-based pilot is manually controlling the UAV or monitoring autonomous operation by the UAV, and backup methods of ATC–ground-based pilot communication (such as dedicated telephone lines).

One specialist said that air traffic controllers also may require special procedures for UAVs operating in reduced vertical separation minimums (RVSM) airspace to prevent upsets caused by wake turbulence.[62]

Moreover, effects of weather should be studied for insights into any relevant issues for commercial UAVs.

"Many UAVs have configurations and characteristics that make them more vulnerable to weather than most manned aircraft," the MITRE report said. "Generally speaking, today's UAVs are lighter, slower and more fragile than their manned counterparts and consequently are more uniquely sensitive to certain meteorological events such as surface/terrain-induced (boundary layer) winds, turbulence, icing, extreme cold and precipitation. Small UAVs and those having a light wing load are especially sensitive. Even with the larger UAVs, weather conditions, such as turbulence, have caused lost [data] links (signal dropout) and even loss of control where conditions exceeded the autopilot's ability to recover. … In most UAV weather accidents … the [UAVs] were not equipped with sensors and the [ground-based pilot] was not fully aware of the hazardous meteorological conditions that existed at the time."

Overall, the European UAV task force said that civil aviation authorities should "establish a common and harmonized reporting system of occurrences for both UAV operators and [air traffic] service providers in order to be able to assess and categorize all possible occurrences, determine appropriate levels of safety and identify key risk areas when UAV operations will be integrated outside restricted airspace."

Work Advances to Update Civil Aviation Regulations

Some specialists in the UAV community and in civil aviation authorities said that they have a common intention to amend regulations rather than to develop new regulations solely for UAVs. Steps have been taken to establish such regulations in several countries. Minimizing UAV-related changes in ATC also is a goal of air traffic services providers.

"Regulation of UAVs [by FAA] is important because it will provide a legal basis for them to operate in [U.S. airspace] for the first time," said the DOD roadmap for military UAVs. "This, in turn, should lead to their acceptance by international and [non-U.S.] civil aviation authorities."

The basic principle for international operations by UAVs comes from Article 8 of the Convention on International Civil Aviation, which in 1944 said, "No aircraft capable of being flown without a pilot shall be flown over the territory of a contracting state without special authorization by that state and in accordance with the terms of such an authorization. Each contracting state undertakes to insure that the flight of such an aircraft without a pilot in regions open to civil aircraft shall be so controlled as to obviate danger to civil aircraft."[63]

The Civil Aviation Safety Authority (CASA) in Australia said that it implemented in 2002 the world's first comprehensive civil aviation regulations for UAVs. In April 2005, CASA launched a project to refine the regulations implemented in 2002 to address airworthiness requirements for Australian UAVs, including design, manufacture and continuing airworthiness. Other civil aviation authorities also have ordered development of required UAV operational concepts, policies, standards, regulations and guidance.

Current Australian regulations exempt the smallest UAVs (called "micro UAVs," with gross weight of 100.0 grams [3.5 ounces] or less) from most of the requirements applicable to large UAVs but operators must comply with rules on hazardous operation, flight in controlled airspace and flight exceeding an altitude of 400 feet above ground level. Large UAVs in Australia include unmanned airships with an envelope capacity greater than 100 cubic meters (3,531 cubic feet), unmanned powered parachutes or UAVs with a gross weight greater than 150 kilograms (331 pounds), and unmanned rotorcraft or powered lift devices with a gross weight greater than 100 kilograms (220 pounds). The large UAVs generally are treated as conventional aircraft in Australian operating rules, requiring a special certificate of airworthiness (restricted category) or an experimental certificate.

Small UAVs are those that do not fit into the other categories; they can be authorized to fly outside an approved area if they are operated clear of populous areas and clear of controlled airspace in Australia; approval by CASA is required for flight at altitudes more than 400 feet above ground level.[64]

Requirements for flights by large UAVs are the most extensive, requiring flight under the control of a certified ground-based pilot (officially called a "UAV controller") and CASA approval of the operation or series of operations along with certification of the UAV operator, and compliance with rules for maintenance; radiotelephony; ATC procedures, clearances and instructions; and operational and equipment specifications for the class of airspace.

In 2004, Italy passed legislation authorizing the National Civil Aviation Authority, in concert with Air Navigation Services Co., to develop regulations enabling Italian military UAVs to operate routinely in restricted areas and corridors of civil airspace under civilian air traffic control, news reports said.[65]

U.K. CAA said, "Currently, an equivalent level of [UAV] safety to that required for 'manned flying' is achieved by both appropriate regulation and restricting peacetime military UAV operations to segregated airspace (i.e., danger areas). Further, there are currently no national procedures which permit either civil [UAVs] or military [UAVs] to routinely fly in nonsegregated airspace. … A significant increase in both civil and military [UAV] flying is anticipated, most of which will require access to all classes of airspace if it is to be both operationally effective and/or commercially viable. To achieve this, [UAVs] will have to be able to meet all existing safety standards, applicable to equivalent manned aircraft types, appropriate to the class (or classes) of airspace within which they are intended to be operated. … To ensure that air traffic controllers are aware that a flight is a UAV flight, all UAV call signs shall include the word 'unmanned.' … There are currently no regulations governing the qualifications required to operate a civil registered UAV in U.K. airspace."[66]

Minimizing UAV-related changes in ATC … is a goal of air traffic services providers.

U.K. CAA guidance includes the following general principles for UAV operation outside of danger areas — which are depicted on CAA charts as permanent/temporary airspace to be avoided by pilots based on current NOTAMs when the area is activated — in U.K. airspace:

- The ground-based pilot continuously must monitor UAV performance and ATC communications, must comply with ATC instructions and must be capable of taking immediate active control of the UAV at all times;
- The UAV must be equipped, as a minimum, with the same types of equipment required for manned aircraft in the class of airspace to be used and an approved method of preventing midair collisions (the method might include "a combination of radar coverage and a chase aircraft or an approved on-board system");
- The UAV must be equipped with an approved method of assuring terrain clearance; and,
- The ground-based pilot must comply with the visual/instrument flight rules applicable to manned aircraft. "Thus, UAVs fitted with nonvisual collision-avoidance systems must still comply with the IFR when [in instrument meteorological conditions (IMC)] (i.e., they may not fly VFR in IMC just because they can 'sense' and avoid; quadrantal/semi-circular rules [for selecting altitudes based on course] will continue to apply."

In Europe, the 2002 European Commission regulation and implementing rules that established the European Aviation Safety Agency (EASA) will require some UAVs to have an EASA airworthiness certificate (i.e., those that are neither experimental nor military and weigh more than 150 kilograms).[67]

In the United States, the qualifications for ground-based pilots have been set by DOD and the Defense Management Contract Agency. UAVs may be operated only by DOD's civilian contractors outside of restricted areas or warning areas when a written agreement with FAA authorizes the operations. Ground-based pilots conducting such operations must have a least a private pilot certificate, an instrument rating, a current annual instrument review, 300 flight hours as pilot-in-command or mission commander (of UAVs or aircraft, including 100 flight hours in a manned aircraft), hold current ground-based pilot certifications (when FAA begins to require ground-based pilot certification) and comply with guidance from the military service about ground-based pilot qualification and currency if these requirements are more restrictive than the Defense Contract Management Agency's requirements.[68]

Other countries, including the Netherlands and Sweden, have emphasized in their UAV airworthiness-certification processes that UAVs should be considered as systems rather than as isolated aircraft, so that adequate consideration can be given to the ground control station, data link systems, systems for autonomous flight and collision avoidance, and related software, the MITRE report said.

"Approvals for [UAV] flight testing and operation have already been granted for some civil projects," said guidance material prepared by the Swedish Aviation Safety Authority. "Applications for military UAVs to be permitted to fly in airspace where civil aviation occurs are expected shortly. … Special (occasional) solutions to compensate for faults or uncertainty in a UAV system may in some cases be necessary. A manned escort plane can be such a solution when the need to see other aircraft is essential and cannot be fulfilled. … Until sufficient positive experience of a UAV system has been acquired, special air traffic controllers could be [provided to separate] UAVs from other traffic within controlled airspace and to coordinate UAV flight paths with other air traffic services units."[69]

Innovations Could Benefit All Civil Airspace Users

How other airspace users will influence proposals for integrating UAVs into civil airspace is not clear, although many already participate in the dozens of working groups established by the worldwide UAV community. Other airspace users — and society as a whole — are expected to look at the broad context of security requirements and the indirect benefits provided by UAVs to the rest of the aviation community. Concerns could be allayed not only by addressing safety issues, but by introducing communication methods, collision-avoidance systems, worldwide data networks, unconventional fuels and autonomous-control capabilities that have collateral applications to manned aircraft.[70]

Accuracy, objectivity and data-driven methods will be required to demonstrate to aviation safety professionals that safety issues are addressed adequately in the context of UAV applications and business opportunities. Flying UAVs in civil airspace of the 21st century recalls risks of aviation in the early 20th century. ■

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2004 Was 'Safest Year Ever' For Air Transport

Despite an increase in passenger traffic, there were fewer fatalities worldwide in 2004 involving large Western-built commercial jets than in each of the previous two years. The number of accidents and the rates of accidents declined for air carriers flying under U.S. Federal Aviation Regulations Part 121, and there were no fatal accidents for scheduled flights under Part 135.

— FSF EDITORIAL STAFF

Although the number of accidents involving large Western-built commercial jets operated by International Air Transport Association (IATA)-member airlines and non-IATA-member airlines increased from 99 in 2003 to 103 in 2004,[1] the number of fatalities in 2004 declined to 428, compared with 663 in 2003. In 2002, 974 people were killed during flight operations.[2]

The industrywide hull-loss accident[3] rate declined 10 percent in 2004, to 0.78 hull losses per million departures, IATA said (Figure 1, page 28).

Giovanni Bisignani, IATA director general and CEO, said, "2004 was the safest year ever for air transport."

Preliminary reports of the number of fatal airline accidents worldwide in 2004, including accidents involving non-Western aircraft, ranged from 26 to 28.[4]

Commercial jets were involved in three controlled-flight-into-terrain (CFIT) accidents in 2004, with 42 total fatalities. (One CFIT accident was a positioning flight for an on-demand [air taxi] operation.) That compared with seven CFIT accidents in 2003, resulting in 203 total fatalities, and five CFIT accidents in 2002, with 357 total fatalities.[5]

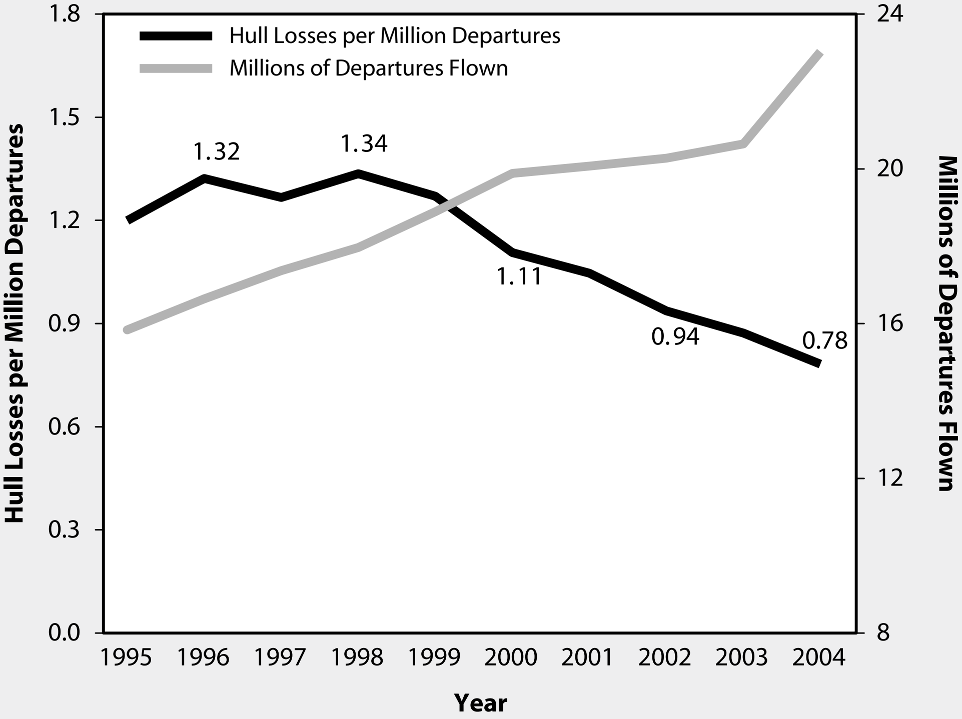
In 2004, more than 1.8 billion passengers traveled in commercial aircraft worldwide.[6]

Other preliminary data for 2004, published by the U.S. National Transportation Safety Board (NTSB), showed that the number of accidents[7] and the accident rates for U.S. air carriers operating under U.S. Federal Aviation Regulations (FARs) Part 121, *Domestic, flag and supplemental operations*, declined in 2004 compared with 2003 (Table 1, page 29). The number of fatal accidents[8] and the rates of fatal accidents per 100,000 flight hours and fatal accidents per 100,000 departures were identical to those of the previous year.

There were no fatal accidents in 2004 involving scheduled (commuter) operations under FARs Part 135, *Operating requirements: Commuter and on demand operations and rules governing*

Figure 1

Western-built Jet Air-transport Traffic and Hull-loss Rates, 1995–2004



Note: A hull loss is defined as an accident in which an aircraft is substantially damaged and is not subsequently repaired for whatever reason, including a financial decision of the owner.

Source: International Air Transport Association

persons on board such aircraft. The fatal-accident rate for Part 135 on-demand operations per 100,000 flight hours was higher than the rate for scheduled Part 121 operations.

NTSB said that 28 total accidents and two fatal accidents occurred involving Part 121 air carriers, compared with 54 total accidents and two fatal accidents in 2003.

[The two fatal Part 121 accidents in 2004 included a British Aerospace (BAe) Jetstream 32 that struck terrain during an instrument approach to Kirksville (Missouri, U.S.) Regional Airport on Oct. 19, with 13 fatalities, and a Convair 580 that struck terrain during a visual approach to Cincinnati/Northern Kentucky (U.S.) International Airport on Aug. 13, with one fatality. The Aug. 13 accident was a nonscheduled Part 121 cargo flight. Both accidents remain under investigation.]

Part 121 scheduled operations in 2004 had a lower accident rate, with 0.124 accidents per 100,000 flight hours and 0.199 accidents per 100,000 departures, than scheduled operations under Part 135, which had 1.515 accidents per 100,000 flight hours and 0.843 accidents per 100,000 departures, NTSB said (Table 2, page 30). The fatal-accident rate was 0.006 accidents per 100,000 flight hours and 0.009 accidents per 100,000 departures for Part 121 scheduled operations. Part 135 on-demand operations had a fatal-accident rate of 0.780 per 100,000 flight hours; the fatal-accident rate based on departures was not available.

There were 11 passenger fatalities and three passenger serious injuries[9] in Part 121 accidents in 2004 — equivalent to 56.5 million enplanements per passenger fatality and 207 million enplanements per passenger serious injury, NTSB said. Including aircraft crewmembers, there were 14 fatalities.

For Part 121 air carriers, the number and rate of major accidents[10] increased in 2004 compared with the previous two years, but the numbers and rates of accidents classified as serious accidents,[11] injury accidents[12] and damage accidents[13] declined (Table 3, page 30).

Part 121 air carriers experienced three hull losses in 2004, for a rate of 0.171 per million flight hours (Table 4, page 31).

Continued on page 31

Table 1
Accidents, Fatalities and Accident Rates, U.S. Air Carriers Operating Under FARs Part 121, Scheduled and Nonscheduled Service (Airlines), 1985–2004

	Accidents		Fatalities					Accidents per 100,000 Flight Hours		Accidents per 1,000,000 Miles Flown		Accidents per 100,000 Departures	
Year	All	Fatal	Total	Aboard	Flight Hours	Miles Flown	Departures	All	Fatal	All	Fatal	All	Fatal
1985	21	7	526	525	8,709,894	3,631,017,000	6,306,759	0.241	0.080	0.0058	0.0019	0.333	0.111
1986*	24	3	8	7	9,976,104	4,017,626,000	7,202,027	0.231	0.020	0.0057	0.0005	0.319	0.028
1987*	34	5	232	230	10,645,192	4,360,521,000	7,601,373	0.310	0.038	0.0076	0.0009	0.434	0.053
1988*	30	3	285	274	11,140,548	4,503,426,000	7,716,061	0.260	0.018	0.0064	0.0004	0.376	0.026
1989	28	11	278	276	11,274,543	4,605,083,000	7,645,494	0.248	0.098	0.0061	0.0024	0.366	0.144
1990	24	6	39	12	12,150,116	4,947,832,000	8,092,306	0.198	0.049	0.0049	0.0012	0.297	0.074
1991	26	4	62	49	11,780,610	4,824,824,000	7,814,875	0.221	0.034	0.0054	0.0008	0.333	0.051
1992	18	4	33	31	12,359,715	5,039,435,000	7,880,707	0.146	0.032	0.0036	0.0008	0.228	0.051
1993	23	1	1	0	12,706,206	5,249,469,000	8,073,173	0.181	0.008	0.0044	0.0002	0.285	0.012
1994*	23	4	239	237	13,124,315	5,478,118,000	8,238,306	0.168	0.030	0.0040	0.0007	0.267	0.049
1995	36	3	168	162	13,505,257	5,654,069,000	8,457,465	0.267	0.022	0.0064	0.0005	0.426	0.035
1996	37	5	380	350	13,746,112	5,873,108,000	8,228,810	0.269	0.036	0.0063	0.0009	0.450	0.061
1997	49	4	8	6	15,838,109	6,696,638,000	10,318,383	0.309	0.025	0.0073	0.0006	0.475	0.039
1998	50	1	1	0	16,816,555	6,736,543,000	10,979,762	0.297	0.006	0.0074	0.0001	0.455	0.009
1999	51	2	12	11	17,555,208	7,101,314,000	11,308,762	0.291	0.011	0.0072	0.0003	0.451	0.018
2000	56	3	92	92	18,299,257	7,524,027,000	11,468,229	0.306	0.016	0.0074	0.0004	0.488	0.026
2001*	46	6	531	525	17,814,191	7,294,191,000	10,954,832	0.236	0.011	0.0058	0.0003	0.383	0.018
2002	41	0	0	0	17,290,198	7,192,501,000	10,508,473	0.237	—	0.0057	—	0.390	—
2003	54	2	22	21	17,433,964	7,280,383,000	10,422,862	0.310	0.011	0.0074	0.0003	0.518	0.019
2004	28	2	14	14	17,575,000	7,378,300,000	10,785,000	0.159	0.011	0.0038	0.0003	0.260	0.019

FARs = U.S. Federal Aviation Regulations

Note: 2004 data are preliminary.

Flight hours, miles and departures are compiled by the U.S. Federal Aviation Administration.

Since March 20, 1997, aircraft with 10 or more seats used in scheduled passenger service have been operated under FARs Part 121.

Years followed by the symbol * are those in which an illegal act was responsible for an occurrence in this category. These acts, such as suicide, sabotage and terrorism, are included in the totals for accidents and fatalities but are excluded from accident rates. Other than the people aboard aircraft who were killed, fatalities resulting from the Sept. 11, 2001, terrorist act are excluded from this table.

Source: U.S. National Transportation Safety Board

Table 2
Accidents, Fatalities and Accident Rates, U.S. Aviation, 2004

	Accidents		Fatalities				Accidents per 100,000 Flight Hours		Accidents per 100,000 Departures	
	All	Fatal	Total	Aboard	Flight Hours	Departures	All	Fatal	All	Fatal
U.S. air carriers operating under FARs Part 121										
Scheduled	21	1	13	13	17,000,000	10,547,000	0.124	0.006	0.199	0.009
Nonscheduled	7	1	1	1	575,000	238,000	1.217	0.174	2.941	0.420
U.S. air carriers operating under FARs Part 135										
Scheduled	5	—	—	—	330,000	593,000	1.515	—	0.843	—
Nonscheduled	68	24	65	64	3,072,000	—	2.210	0.780	—	—

FARs = U.S. Federal Aviation Regulations

Note: All data are preliminary.

Flight hours and departures are compiled and estimated by the U.S. Federal Aviation Administration.

Departure information for nonscheduled FARs Part 135 operations is not available.

Source: U.S. National Transportation Safety Board

Table 3
Accidents and Accident Rates by NTSB Classification, U.S. Air Carriers Operating Under FARs Part 121, 1985–2004

	Accidents					Accidents per Million Flight Hours			
Year	Major	Serious	Injury	Damage	Flight Hours (millions)	Major	Serious	Injury	Damage
1985	8	2	5	6	8.710	0.918	0.230	0.574	0.689
1986	4	0	14	6	9.976	0.401	0.000	1.403	0.601
1987	5	1	12	16	10.645	0.470	0.094	1.127	1.503
1988	4	2	13	11	11.141	0.359	0.180	1.167	0.987
1989	8	4	6	10	11.275	0.710	0.355	0.532	0.887
1990	4	3	10	7	12.150	0.329	0.247	0.823	0.576
1991	5	2	10	9	11.781	0.424	0.170	0.849	0.764
1992	3	3	10	2	12.360	0.243	0.243	0.809	0.162
1993	1	2	12	8	12.706	0.079	0.157	0.944	0.630
1994	4	0	12	7	13.124	0.305	0.000	0.914	0.533
1995	3	2	14	17	13.505	0.222	0.148	1.037	1.259
1996	6	0	18	13	13.746	0.436	0.000	1.309	0.946
1997	2	4	24	19	15.838	0.126	0.253	1.515	1.200
1998	0	3	21	26	16.817	0.000	0.178	1.249	1.546
1999	2	2	20	27	17.555	0.114	0.114	1.139	1.538
2000	3	3	20	30	18.299	0.109	0.109	1.093	1.475
2001	5	1	19	21	17.814	0.281	0.056	1.067	1.179
2002	1	1	14	25	17.290	0.058	0.058	0.810	1.446
2003	2	3	24	25	17.434	0.115	0.172	1.377	1.434
2004	3	0	13	12	17.575	0.171	0.000	0.740	0.683

FARs = U.S. Federal Aviation Regulations NTSB = U.S. National Transportation Safety Board

Note: Since March 20, 1997, aircraft with 10 or more seats used in scheduled passenger service have been operated under FARs Part 121.

A *major accident* is defined as one in which a Part 121 aircraft was destroyed, or there were multiple fatalities or there was one fatality and a Part 121 aircraft was substantially damaged.

A *serious accident* is defined as one in which there was one fatality without substantial damage to a Part 121 aircraft or there was at least one serious injury and a Part 121 aircraft was substantially damaged.

An *injury accident* is defined as one with at least one serious injury and without substantial damage to a Part 121 aircraft.

A *damage accident* is defined as one in which no person was killed or seriously injured but in which any aircraft was substantially damaged.

Source: U.S. National Transportation Safety Board

Both the number and rate were the highest of any year since 2001.

Accidents involving commuter flights under Part 135 increased to five in 2004, compared with two the previous year (Table 5, page 32). The rates of 1.515 accidents per 100,000 flight hours and 0.843 accidents per 100,000 departures also represented increases compared with 2003. There were no fatal accidents in the category.

In 2004, on-demand operations under Part 135 resulted in 68 accidents, compared with 75 in 2003. The 24 fatal accidents in 2004 compared with 18 in 2003 (Table 6, page 33). The 2004 accident rate per 100,000 flight hours in Part 135 on-demand operations declined from the 2003 rate, and the fatal-accident rate increased from the 2003 rate.

The U.S. data are available on the Internet at <www.ntsb.gov/aviation>.■

Table 4

Number and Rate of Destroyed Aircraft, U.S. Air Carriers Operating Under FARs Part 121, 1985–2004

Year	Hull Losses	Flight Hours (millions)	Hull Losses per Million Flight Hours
1985	8	8.710	0.918
1986	2	9.976	0.200
1987	5	10.645	0.470
1988	3	11.141	0.269
1989	7	11.275	0.621
1990	3	12.150	0.247
1991	5	11.781	0.424
1992	3	12.360	0.243
1993	1	12.706	0.079
1994	3	13.124	0.229
1995	3	13.505	0.222
1996	5	13.746	0.364
1997	2	15.838	0.126
1998	0	16.817	0.000
1999	2	17.555	0.114
2000	3	18.299	0.164
2001	5	17.814	0.281
2002	1	17.290	0.058
2003	2	17.434	0.115
2004	3	17.575	0.171

FARs = U.S. Federal Aviation Regulations

Note: Since March 20, 1997, aircraft with 10 or more seats used in scheduled passenger service have been operated under FARs Part 121.

Source: U.S. National Transportation Safety Board

Notes

1. International Air Transport Association (IATA) news release. March 7, 2005. <www.iata.org/pressroom>.
2. International Air Transport Association (IATA) data for 2002 and 2003 were cited by *Airwise News*, April 27, 2005.
3. A hull loss is defined by IATA as "an accident in which an aircraft is substantially damaged and is not subsequently repaired for whatever reason, including a financial decision of the owner."
4. Data were included in *Flight International* Volume 67 (Jan. 25–31, 2005); Airclaims, cited in *Air Safety Week*, Jan. 10, 2005; and Aviation Safety Network, Jan. 1, 2005 <http://aviation-safety.net/pubs>.
5. Bateman, C. Don, chief engineer for avionics safety systems, Honeywell. E-mail communications with Darby, Rick. Alexandria, Virginia, U.S., May 9, 2005, and May 10, 2005. Flight Safety Foundation, Alexandria, Virginia, U.S.
6. IATA, *op. cit.*
7. The U.S. National Transportation Safety Board (NTSB) defines an *accident* as "an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage."
8. NTSB defines a *fatal accident* as one that results in death within 30 days of the accident.
9. NTSB defines a *serious injury* as one that requires hospitalization for more than 48 hours, commencing within seven days from the date the injury was received; results in a fracture of any bone (except simple fractures of fingers, toes or nose); causes severe hemorrhages, nerve, muscle or tendon damage; involves any internal organ; or involves second-degree burns or third-degree burns, or any burns affecting more than 5 percent of the body surface.

Table 5

Accidents, Fatalities and Accident Rates, U.S. Air Carriers Operating Under FARs Part 135, Scheduled Service, 1985–2004

	Accidents		Fatalities					Accidents per 100,000 Flight Hours		Accidents per 1,000,000 Miles Flown		Accidents per 100,000 Departures	
Year	All	Fatal	Total	Aboard	Flight Hours	Miles Flown	Departures	All	Fatal	All	Fatal	All	Fatal
1985	18	7	37	36	1,737,106	300,817,000	2,561,463	1.036	0.403	0.0598	0.0233	0.703	0.273
1986	14	2	4	4	1,724,586	307,393,000	2,798,811	0.812	0.116	0.0455	0.0065	0.500	0.071
1987	33	10	59	57	1,946,349	350,879,000	2,809,918	1.695	0.514	0.0940	0.0285	1.174	0.356
1988	18	2	21	21	2,092,689	380,237,000	2,909,005	0.860	0.096	0.0473	0.0053	0.619	0.069
1989	19	5	31	31	2,240,555	393,619,000	2,818,520	0.848	0.223	0.0483	0.0127	0.674	0.177
1990	15	3	6	4	2,341,760	450,133,000	3,160,089	0.641	0.128	0.0333	0.0067	0.475	0.095
1991	23	8	99	77	2,291,581	433,900,000	2,820,440	1.004	0.349	0.0530	0.0184	0.815	0.284
1992*	23	7	21	21	2,335,349	507,985,000	3,114,932	0.942	0.300	0.0433	0.0138	0.706	0.225
1993	16	4	24	23	2,638,347	554,549,000	3,601,902	0.606	0.152	0.0289	0.0072	0.444	0.111
1994	10	3	25	25	2,784,129	594,134,000	3,581,189	0.359	0.108	0.0168	0.0050	0.279	0.084
1995	12	2	9	9	2,627,866	550,377,000	3,220,262	0.457	0.076	0.0218	0.0036	0.373	0.062
1996	11	1	14	12	2,756,755	590,727,000	3,515,040	0.399	0.036	0.0186	0.0017	0.313	0.028
1997	16	5	46	46	982,764	246,029,000	1,394,096	1.628	0.509	0.0650	0.0203	1.148	0.359
1998	8	0	0	0	353,670	50,773,000	707,071	2.262	—	0.1576	—	1.131	—
1999	13	5	12	12	342,731	52,403,000	672,278	3.793	1.459	0.2481	0.0954	1.934	0.744
2000	12	1	5	5	369,535	44,943,000	603,659	3.247	0.271	0.2670	0.0223	1.988	0.166
2001	7	2	13	13	300,432	43,099,000	558,052	2.330	0.666	0.1624	0.0464	1.254	0.358
2002	7	0	0	0	273,559	41,633,000	513,452	2.559	—	0.1681	—	1.363	—
2003	2	1	2	2	319,206	47,404,000	580,805	0.627	0.313	0.0422	0.0211	0.344	0.172
2004	5	0	0	0	330,000	51,100,000	593,000	1.515	—	0.0978	—	0.843	—

FARs = U.S. Federal Aviation Regulations

Note: 2004 data are preliminary.

Flight hours, miles and departures are compiled by the U.S. Federal Aviation Administration (FAA).

Since March 20, 1997, aircraft with 10 or more seats used in scheduled passenger service have been operated under FARs Part 121.

Years followed by the symbol * are those in which an illegal act was responsible for an occurrence in this category. These acts, such as suicide, sabotage and terrorism, are included in the totals for accidents and fatalities but are excluded from accident rates.

Based on a February 2002 FAA legal interpretation provided to the U.S. National Transportation Safety Board (NTSB), any FARs Part 135 operation conducted with no revenue passengers aboard is considered a nonscheduled flight operation. This interpretation has been applied to accidents beginning in the year 2002. It has not been applied retroactively to 36 accidents, nine of them fatal, that occurred during the period 1983–2001.

Source: U.S. National Transportation Safety Board

Table 6
Accidents, Fatalities and Accident Rates, U.S. Air Carriers Operating Under FARs Part 135, Nonscheduled Service, 1985–2004

	Accidents		Fatalities			Accidents per 100,000 Flight Hours	
Year	All	Fatal	Total	Aboard	Flight Hours	All	Fatal
1985	157	35	76	75	2,570,000	6.11	1.36
1986	118	31	65	61	2,690,000	4.39	1.15
1987	96	30	65	63	2,657,000	3.61	1.13
1988	102	28	59	55	2,632,000	3.88	1.06
1989	110	25	83	81	3,020,000	3.64	0.83
1990	107	29	51	49	2,249,000	4.76	1.29
1991	88	28	78	74	2,241,000	3.93	1.25
1992	76	24	68	65	2,844,000	2.67	0.84
1993	69	19	42	42	2,324,000	2.97	0.82
1994	85	26	63	62	2,465,000	3.45	1.05
1995	75	24	52	52	2,486,000	3.02	0.97
1996	90	29	63	63	3,220,000	2.80	0.90
1997	82	15	39	39	3,098,000	2.65	0.48
1998	77	17	45	41	3,802,000	2.03	0.45
1999	74	12	38	38	3,204,000	2.31	0.37
2000	80	22	71	68	3,930,000	2.04	0.56
2001	72	18	60	59	2,997,000	2.40	0.60
2002	60	18	35	35	2,911,000	2.06	0.62
2003	75	18	42	40	2,927,000	2.56	0.61
2004	68	24	65	64	3,072,000	2.21	0.78

FARs = U.S. Federal Aviation Regulations

Note: 2004 data are preliminary.

Flight hours are estimated by the U.S. Federal Aviation Administration (FAA). Miles flown and departure information for nonscheduled Part 135 operations are not available.

In 2002, FAA changed its estimate of nonscheduled (on-demand) activity. The revision was applied retroactively, beginning with the year 1992. In 2003, FAA again revised flight-activity estimates for 1999 to 2002.

Source: U.S. National Transportation Safety Board

10. NTSB classifies as a *major accident* one in which a U.S. Federal Aviation Regulations (FARs) Part 121 aircraft was destroyed, or there were multiple fatalities or there was one fatality and a Part 121 aircraft was substantially damaged.

11. NTSB classifies as a *serious accident* one in which there was one fatality without substantial damage to a Part 121 aircraft or there was at least one serious injury and a Part 121 aircraft was substantially damaged.

12. NTSB classifies as an *injury accident* a nonfatal accident with at least one serious injury and without substantial damage to a Part 121 aircraft.

13. NTSB classifies as a *damage accident* an accident in which no person was killed or seriously injured, but in which any aircraft was substantially damaged. organ; or involves second-degree burns or third-degree burns, or any burns affecting more than 5 percent of the body surface.

‘Root Causes’ in the System Can Underlie Human Error

Operational human error in accidents is often only the final manifestation of ‘latent’ human error in management, design and maintenance. An open organizational culture and user-centered design are said to be among the ways to minimize human error.

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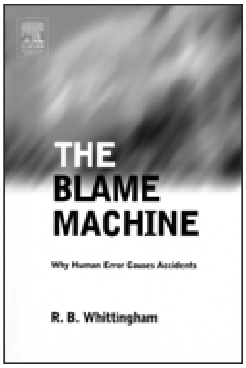

Books

The Blame Machine: Why Human Error Causes Accidents. Whittingham, R.B. Oxford, England: Elsevier Butterworth-Heinemann, 2004. 288 pp. Figures, tables, appendix, references, index.

“In the immediate aftermath of a serious accident, there is a natural tendency, especially by the media, quickly to suggest a cause and maybe attribute blame,” says the author. “Quite often the words ‘it is believed the accident was a result of human error’ are heard. There is an air of finality about this statement, it being implicit that no more can be said or done. The inevitable has happened. [It is hoped that] the accident investigation which is held later does not accept human error as inevitable, but goes on to reveal the underlying reasons why the error occurred.”

The book focuses on system faults that can make errors more likely, the author says. Part I classifies types of errors and suggests ways of estimating their frequency, so that their frequency can be minimized. Part II comprises studies of serious accidents in various industries, including aviation, to show how systemic errors were implicated.

“The direct cause [of the accidents discussed] is usually a human error, while the root cause tends to be the main underlying system fault that made the error possible or more likely,” says the author. “The contributory causes are less significant factors or systems that also influenced the probability of error. The system of interest may be an item of equipment, a procedure or an organizational system.”

Although some instances of human error are “active” — occurring in operations — many are “latent,” the author says. Types of latent errors that he discusses in connection with pertinent accidents include organizational and management errors, design errors and maintenance errors.

Among the factors that can minimize human error that is encouraged by systemic failure, the author says, are the following:

- An open organizational culture that acknowledges mistakes and learns from them, emphasizing underlying causes more than individual actions; and,
- User-centered design, in which “the design of the system is matched as closely as possible

to human capabilities and limitations." This is contrasted with system-centered design, in which the system rather than the human operating it is the focus of attention. The author says, "There are numerous examples of complex technological systems that have been designed mainly with system functionality in mind, ignoring the capabilities and limitations of the user. Such systems invariably result in degraded levels of human performance, with grave consequences for productivity, equipment availability and safety."

The Wright Brothers Legacy: Orville and Wilbur Wright and Their Aeroplanes. Burton, Walt; Findsen, Owen. New York, New York, U.S.: Harry N. Abrams, 2003. 224 pp. Photographs.

"An important aspect of the Wright Brothers' quest to fly was their use of photography, because it provided irrefutable evidence that on that cold and barren stretch of beach [at Kitty Hawk, North Carolina, U.S.] they had succeeded," says Alexander Lee Nyerges, director and CEO of the Dayton [Ohio, U.S.] Art Institute, in his foreword. "It is quite fitting that the Wrights had the foresight to employ photography in their endeavors. … Not only did they use photography as a documentary tool, but they took great pains to ensure that it was dramatic and aesthetically powerful. The beauty and majesty of the 'first flight' photograph is not the result of good fortune alone. The Wrights planned to capture that fleeting moment on film. And they were successful."

The book was published in connection with an exhibition at the Dayton Art Institute, of which Orville Wright was a founding trustee. It includes photographs — black-and-white, sepia and hand-tinted — by, and of, the Wright brothers. Wright-related material, including postcards, news photographs, magazine covers and souvenirs, also is represented.

"Starting about 1898, Wilbur and Orville purchased a four[-inch] by five[-inch] [10-centimeter by 13-centimeter] glass-plate camera and built a darkroom in a shed in their backyard," say the authors. "It began as another of their many hobbies, but when they began flying gliders at Kitty Hawk in 1900, their photographs served as a visual record of their flying experiments. … Between 1900 and 1906, they made hundreds of pictures of gliders and airplanes in flight, including their famous image, taken Dec. 17, 1903, of the first moment that man left the ground in a heavier-than-air, powered flying machine."

John Daniels, one of the crewmembers from a nearby life-saving station who had volunteered as assistants and witnesses, took the Dec. 17 photograph. "Daniels forgot about the camera, but when Orville inspected it [after the flight], the shutter had been released," the authors say. "Daniels had automatically squeezed his hand in the excitement. It was the only photograph he ever took. And it was not until days later, when the brothers went into their darkroom in the shed behind their Dayton home, that they held the glass plate up to the safe light and saw that they had the picture, one of the most famous photographs ever taken."

The photograph, which shows the Flyer, as the airplane was called, after it had risen from the launching track, with Orville stretched out at the controls and Wilbur running alongside, is reproduced in a double-page spread.

Both the text and the photographs follow the careers of the brothers as they continued to develop later airplane models and worked to create a successful business from their invention. Although they never fully capitalized on their work or created a long-lasting aviation manufacturing company, the Wright brothers are recognized today as outstanding inventors and craftsmen who turned a page of history and changed the ways that the world pursues business, pleasure, national defense and many other aspects of life.

Reports

The Airport System Planning Process. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5070-7. Nov. 10, 2004. Figures, appendixes, glossary, references. 83 pp. Available from FAA via the Internet at <www.airweb.faa.gov> or by mail.*

FAA says that the primary purpose of airport system planning is to study the performance and interaction of an entire aviation system to understand the interrelationship of member airports. These may include airports serving a large metropolitan area, a single state or several bordering states within the United States. The airport system may include all types and combinations of airports, heliports, spaceports (operations involving horizontally launched reusable vehicles) and seaplane bases.

A systemwide planning process determines the type, extent, location, timing and costs of development needed to establish or maintain a viable system of airports in a specific geographic area. Four main activities of the process are as follows:

- Conduct an overall needs assessment;
- Determine cost estimates and funding sources;
- Identify standards prescribed by federal, state, regional and local governing bodies (e.g., environmental considerations); and,
- Implement studies, surveys and other actions to determine specific needs.

The product of the process is a cost-effective plan of action consistent with established goals and objectives that contributes to local and national transportation systems and serves aviation-user requirements.

This AC is a guidance document, organized to guide planners through the process. The intended audience includes members of the public, government agencies and regulatory entities, planning commissions, airport proprietors, and members of the aviation community.

The AC identifies reports, books and other reference materials from academia, special-interest organizations, FAA, the U.S. Department of Transportation, and state and local organizations.

[*The Airport System Planning Process* cancels AC 150/5050-3B, *Planning the State Aviation System*, dated January 1989, and AC 150/5070-5, *Planning the Metropolitan Airport System*, dated May 1970. *The Airport System Planning Process* AC incorporates guidance information from previously canceled AC 150/5050-5, dated November 1975.]

Caring for Precious Cargo, Part II: Behavioral Techniques for Emergency Aircraft Evacuations With Infants Through the Type III Overwing Exit. U.S. Federal Aviation Administration (FAA) Office of Aerospace Medicine. DOT/FAA/AM-05/2. Final report. March 2005. Corbett, Cynthia L. Figures, tables, appendixes, references. 24 pp. Available on the Internet at <www.cami.jccbi.gov> or through NTIS.**

In 1995, FAA estimated that infant enplanements represented approximately 1 percent of all passenger enplanements. FAA has projected 80 million infant enplanements for the 10-year period, 2000–2009. An accurate number of child passengers flying on U.S.-registered carriers is not easily obtainable by airlines or government organizations because children younger than two years can fly seated on an adult's lap and without a purchased ticket.

The report says that there are few recommended procedures for management of these "invisible" passengers in emergencies, and their effect on emergency evacuations is generally unknown. The intent of this study was to identify a set of recommended procedures for passengers with infants and small children to follow when evacuating an airplane using Type III overwing exits.

Simulated overwing evacuations were conducted with adult passengers, some of whom carried anthropomorphic dummies representing infants ranging in age from two months to 24 months. During the first and last trials, no instructions were given as to how the dummies should be carried. In intervening trials, passenger carriers were told to follow printed instructions for carrying infant dummies horizontally, carrying them vertically and passing them to people who already had exited the passageway.

Results showed that dummy size, carrying method and maneuvers through an exit with an infant affected egress speed. Carrying an infant dummy either horizontally or vertically permitted faster egress than passing the dummy through the exit to a waiting adult.

Most participants said that carrying an infant vertically against the body was the easiest method, except for larger, 24-month dummies. Larger dummies were slightly easier to pass through an exit to a waiting person. "Results confirm that passing an infant to another participant produces slower egress than carrying the infant," the report says. The report also compares individual egress times for passengers with infants and for passengers without infants, noting that egress with infants did not significantly influence egress times of other individuals.

Participants also identified risks of injuries to infants regardless of the method used, such as an infant's head or limbs striking the exit frame or an infant being dropped as it was passed through an exit to another adult.

An earlier study (DOT/FAA/AM-1/18) had been similarly conducted using Type I floor-level exits with inflatable escape slides. Information obtained from both studies will be used to develop passenger-education materials, pre-evacuation briefings, safety cards and training programs about the safest and most efficient techniques for emergency evacuation of all passengers, especially infants.

Regulatory Materials

LASORS 2005. U.K. Civil Aviation Authority (CAA), 2005. Figures, tables, appendixes, illustrations, photographs, glossaries, references, index, cross-references. 608 pp. Available on the Internet at <www.caa.co.uk> or from The Stationery Office (TSO).***

The U.K. CAA is empowered by the U.K. Air Navigation Order (ANO) to grant European Joint Aviation Authorities (JAA) and U.K. flight crew licenses and associated ratings, as appropriate.

This book says, "A holder of a Joint Aviation Regulations–Flight Crew License (JAR-FCL) is entitled to act as a member of flight crew in an aircraft registered in JAA member states within the privileges of the license or rating. A holder of a U.K. national license is entitled to act as a member of flight crew in aircraft registered in the U.K. within the privileges of the license or rating concerned."

LASORS 2005 (LAS: Licensing Administration and Standardization; ORS: Operating Requirements and Standards) explains the responsibilities and requirements of JAA and U.K. national licenses and associated ratings and explains administrative procedures for issuance, revalidation and renewal. *LASORS 2005* is designed "to give pilots a one-stop reference for all aspects of safe airplane operation," the CAA says.

The "LAS" section combines into one source all flight crew licensing information from the JAR-FCL, the U.K. ANO, Aeronautical Information Circulars (AICs) and the old U.K. Civil Aviation Papers (CAPs) 53/54.

LAS encompasses licensing and standardization procedures as applied by the U.K. CAA Safety Regulation Group. It provides guidance on how licenses and ratings are obtained and revalidated. Subparts link information to locations within JAR-FCL documentation.

The following licenses are discussed: flight radio telephony operator, private pilot, commercial pilot, airline transport pilot and flight engineer. Ratings discussed include instrument, IMC (instrument meteorological conditions) and night qualification; type and class; and instructor.

The "ORS" section focuses on private pilots of airplanes. The CAA says, however, that the information and advice are relevant to all pilots whatever their experience or type of aircraft flown. Information specific to helicopter pilots and balloon pilots is included.

LASORS is published annually. Interim changes, additions and updates to regulations and procedures are transmitted through AICs and also are published on the Internet.

Standards for Airport Markings. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5340-1H. Change 2. Dec. 6, 2004. References. 12 pp. Available from FAA via the Internet at <www.airweb.faa.gov> or from the U.S. Government Printing Office.****

FAA says, "By Jan. 1, 2007, airport operators holding an airport operating certificate issued under U.S. Federal Aviation Regulations (FARs) Part 139, *Certification of Airports*, must comply with POFZ/TERPS [precision obstacle-free zone/terminal instrument procedures] marking and sign standards."

Change 2 to the AC, *Standards for Airport Markings*, reflects revisions to AC 150/5300-13, *Airport Design*. Change 2 incorporates new mandatory hold markings, primarily in the section titled "Holding Position Markings for Instrument Landing System (ILS)/Precision Obstacle-free Zone (POFZ)."

Changes are made to the standards for marking the boundary of the POFZ and to holding positions of Category (CAT) II/III operations.

Revisions to related ACs and FAA manuals, such as new separation standards for some taxiways and changes in sign standards, are reflected in Change 2. Other affected FAA documents are identified.

Airworthiness Certification of Civil Aircraft, Engines, Propellers, and Related Products Imported to the United States. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 21-23B. Nov. 17, 2004. Figures, appendixes, references. 68 pp. Available from FAA via the Internet at <www.airweb.faa.gov> or from the U.S. Department of Transportation (USDOT).*****

The AC says, "FAA does not issue standard airworthiness certificates, nor grant airworthiness approvals, for aeronautical products manufactured in a country with which the [United States] does not have a BAA [Bilateral Airworthiness Agreement] or a BASA [Bilateral Airworthiness Safety Agreement] with IPA [Implementation Procedures for Airworthiness] for the kinds of products concerned. [FAA] must issue a type certificate prior to the issuance of an FAA standard airworthiness certificate."

BAA and BASA agreements are described in general terms, and countries that are exceptions are noted. Bilateral agreements related to airworthiness are listed by country, agreement type, and application or scope of U.S. acceptance. A tabular list of products eligible for U.S. importation is included with notations specific to participating countries — product types (e.g., aircraft, engines and parts), agreement dates and other information.

This AC offers guidance on some of the most common situations encountered in the design-approval process for FAA type certification or for FAA Technical Standard Order (TSO) design approval. Guidance for obtaining FAA airworthiness certification or approval of civil aeronautical products to be imported to the United States has been updated to reflect the latest BASA IPAs.

References to related FAA documents, contact information for FAA directorates and their assigned product responsibilities, and Internet addresses for obtaining the text of BAAs and BASAs are included.

[This AC cancels AC 21-23A, *Airworthiness Certification of Civil Aircraft, Engines, Propellers, and Related Products Imported to the United States,* dated Oct. 20, 2000.]

Sources

*U.S. Federal Aviation Administration
800 Independence Ave. SW
Washington, DC 20591 U.S.

**National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161 U.S.
Internet: <www.ntis.gov>

*** The Stationery Office
TSO–London
51 Nine Elms Lane
London SW8 5DR U.K.
Internet: <www.tso.co.uk>

**** U.S. Government Printing Office
732 N. Capitol Street NW
Washington, DC 20401 U.S.
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Subsequent Distribution Office
Ardmore East Business Center
3341 Q 75th Avenue
Landover, MD 20785 U.S.

Severe Vibration Accompanies Braking During Landing Rollout

After the landing at an airport in Wales, ground personnel found what appeared to be brake parts on the runway.

— 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

Investigation Reveals Broken Landing-gear Torsion Link

Boeing 737. Minor damage. No injuries.

After a night flight from Spain to Wales, the crew conducted an instrument landing system (ILS) approach to Runway 30 with anti-skid "ON," autobrakes "OFF" and 30 degrees of flap. Winds were from 040 degrees at 20 knots, gusting to 31 knots.

The crew said that the landing was "firm but not heavy and without excessive sideways drift." The crew selected reverse thrust and applied the wheel brakes.

"Almost immediately, the crew experienced very heavy vibration and felt the aircraft pulling to the left," the report said. "Braking application was reduced, and the vibration lessened. Firm braking was again applied at an estimated 60 knots, and extremely heavy vibration again occurred. Both pilots felt a significant lateral acceleration to the left. … The commander used the tiller in an attempt to regain the runway centerline, and he brought the aircraft to a halt on the runway."

Aircraft rescue and fire fighting personnel found no fire but said that brake parts appeared to be on the runway. The airplane was shut down on the runway, and passengers were disembarked.

One day before the incident, another pilot said that after a normal landing, he felt "an unusual juddering" through the rudder pedals when he applied heavy braking. The vibration stopped as braking was eased.

Examination of the airplane revealed that the lower torsion link on the left main landing gear had broken "at a point where a cutout in the flange of the link formed two 'T' section limbs, both of which had fractured," the report said. "The fractures had resulted from overload, approximately in the plane of the link, with the left limb having failed first and the right limb fracture showing signs of very low-cycle, very high-stress load reversals."

The report said that the manufacturer had attributed similar failures over a number of years to excessive wear of the torsion link apex joint.

Delayed Repairs Cited in Excess-trim Incident

Airbus A300-600. No damage. One minor injury.

During a climb to cruise altitude with the autopilot (AP) engaged, the flight crew for the domestic flight in Germany observed that the airplane was about to exceed the maximum allowable airspeed (V_{MO}). They reduced the preset speed and selected a higher climb rate, then observed that the airspeed was continuing to increase and that the nose was beginning to pitch down. They disengaged the AP and, while hand-flying the airplane and establishing the proper flight attitude, found that excessive nose-down trim had been applied.

"A great amount of control force had to be applied until the wrong trim could be correct[ed] by means of the electrical trim device," the incident report said. "Vertical acceleration was so great during the re-establishment of the original flight attitude that one [cabin] crewmember fell and injured herself slightly. The flight was continued with disengaged AP and no further incidents."

In the A300-600, the AP moves the elevator, and the trim system 1 (PTS 1) adjusts the horizontal stabilizer; the report said that these functions are intended to maintain the horizontal stabilizer in the neutral position. In the event that PTS 1 is not available or that it fails, a backup trim system (PTS 2) controls the horizontal stabilizer.

The airplane's APs were checked during periodic maintenance two days before the incident, and a malfunction was corrected by changing components. During a flight the day before the incident, two irregularities were observed: "It was only possible to adjust the [horizontal stabilizer] if PTS 1 was disengaged, and if AP 2 was engaged, the [horizontal stabilizer] was always set to 'pitch down.'" The irregularities were noted in the technical logbook.

Repairs to the PTS 1 irregularity were postponed, with reference to the minimum equipment lists, because of lack of time. The PTS 2/AP 2 irregularity was checked, no fault was identified, and the problem was signed off as "fixed." The airplane was returned to service.

The report said that causes of the incident were:

- "As a result of the deferred elimination of a fault on PTS 1, the AP could be operated with PTS 2 only;
- "There was a fault on PTS 2 for which there was no confirmation or elimination;
- "At a certain airspeed, the signal interruption between engaged AP 2 and PTS 2 caused a continuous change of the [horizontal stabilizer] in the direction of pitch down;
- "Because of a system deficiency caused by [a software error], the continuous change of the [horizontal stabilizer] did not result in a warning and the self-deactivation of the system; [and,]
- "The prescribed procedure for abnormal functions of the horizontal stabilizer [trim] was not executed in time."

Engine Damaged By High-pressure Compressor-blade Failure

Boeing 767. Minor damage. No injuries.

After departure from an airport in Australia on a flight to Brunei, as the crew flew the airplane through 11,000 feet, they heard a loud bang and observed an elevated exhaust gas temperature (EGT), accompanied by a decrease in power from the right engine.

They then observed that the right EGT indicated 662 degrees Celsius (C; 1,224 degrees Fahrenheit

[F]), 12 degrees C (22 degrees F) higher than the maximum operating temperature, for 22 seconds. They closed the throttle for the right engine; declared mayday, a distress condition; and returned to the departure airport for a single-engine, overweight landing.

An investigation revealed that the high-pressure section of the engine could not be rotated and that there was molten metal debris in the exit screens of a bleed-air valve and metal spray in the exhaust duct. The accident report said that the engine damage was "consistent with the failure of a sixth-stage [high-pressure compressor] blade." The report said that the blade had failed because of "high cyclic stress … in turbulent airflow created by [an] off-schedule stator-vane angle."

Loose Fuel Line Cited in Engine Failure

Piper PA-31-350 Chieftain. No damage. No injuries.

Daytime instrument meteorological conditions prevailed for the flight from an airport in Australia. Soon after departure, the pilot observed "light aerodynamic shuddering" through the airframe; he considered this "an idiosyncrasy of this particular aircraft" and continued the flight, the report said.

Later, the right propeller speed fluctuated and the right engine misfired. The pilot adjusted the propeller lever for the right engine, checked the fuel flow and initiated a climb. At 9,000 feet, the misfiring by the right engine increased, the exhaust-gas-temperature gauge indicated "above the redline and in excess of normal operating parameters," and the fuel-flow indication was decreasing, the report said.

The pilot shut down the right engine and feathered the right propeller; declared pan-pan, an urgent condition; and prepared for landing at an en route airstrip. The pilot said that during the diversion, he was unable to prevent the airplane from descending below the lowest safe altitude. He believed that the attitude indicator was providing incorrect information, so he began using the attitude indicator on the copilot's panel, observed the ground through a hole in the clouds at about 400 feet, descended and landed the airplane at the airstrip.

A maintenance inspection revealed a loose fuel line on the right engine, which had caused the engine's fuel starvation. The pilot observed that the flaps were extended about five degrees, although the flap selector was in the retracted position.

"The pilot believed that the aerodynamic drag produced by the flaps in that position would have contributed to the inability to maintain altitude with one engine inoperative and may also have caused the shuddering during the takeoff," the report said.

The airplane owner said that the flaps had been in that position "for some time"; they were repaired after the incident.

Maintenance personnel found no problem with the primary attitude indicator.

Cockpit Fills With Smoke During Approach

Cessna 550 Citation II. Minor damage. No injuries.

Nighttime visual meteorological conditions prevailed as the flight crew conducted a positioning flight to England from an airport in Scotland. The crew received vectors from air traffic control for the approach to the destination airport. When the airplane was at 8,000 feet, the crew smelled burning electrical insulation and observed that the passenger cabin was filled with smoke.

The first officer donned his oxygen mask while the captain declared mayday, a distress condition. His communication with air traffic control was hindered by breathing problems caused by the thick smoke entering the cockpit. The smoke also obscured the instrument panel and forward vision. The captain began the "SMOKE REMOVAL" checklist from memory, opening the dump valve to depressurize the airplane and partially clear the smoke, but did not complete all checklist procedures because he considered landing the airplane to be the top priority.

The crew landed the airplane at the destination airport as smoke increased in the cockpit. They stopped the airplane on the runway, shut down both engines and switched off all electrical power. Aircraft rescue and fire fighting personnel arrived as the crew exited the airplane. An inspection revealed no fire, but smoke continued to emerge from the open cabin door for about 20 minutes.

An inspection revealed that the circuit breaker for the motor of the cabin defog fan blower had tripped; the motor was found to be defective.

The report said that completion of the emergency checklists might have removed power from the defective fan and minimized the smoke. Nevertheless, the report said that the captain's decision not to complete all relevant emergency procedures "was influenced by the time available and the need to concentrate on the approach and landing."

Runway Surface Cited in Loss of Braking Action

Cessna 310J. Substantial damage. No injuries.

Daytime visual meteorological conditions prevailed for the business flight in the United States. The pilot said that he was flying a "standard approach" to Runway 21 at an approach speed between 105 knots and 110 knots, with 35 degrees of flap. The airplane touched down about 500 feet to 700 feet (153 meters to 214 meters) past the threshold of the 3,800-foot (1,159-meter) runway, and the pilot immediately applied the brakes. The pilot described braking action as "ineffective." The airplane departed the right side of the runway and struck a hangar, then spun 120 degrees and struck a fuel truck.

The aircraft landing performance chart indicates that, with 35 degrees of flaps and in no-wind conditions, the airplane requires between 766 feet (234 meters) and 1,114 feet (340 meters) for landing. (The report did not discuss wind conditions at the time of the accident.)

The runway surface had been treated eight months before the accident with a coal-tar sealer/rejuvenator that conformed to specifications for road tar. The pilot said that the ineffective braking action was a result of the treatment.

During the accident investigation, an inspector examined the runway surface and described it as "having the consistency of putty." In a skid test using highway vehicle test equipment, the friction rating was categorized as "poor."

The probable cause of the accident was "the poor friction value on the runway rendering braking action inadequate." Contributing factors were "excessive approach speed and the pilot's inability to maintain directional control of the aircraft."

Airplane Strikes Terrain During Crosswind Landing

Cirrus Design SR-22. Substantial damage. No injuries.

Daytime visual meteorological conditions prevailed for the business flight in the United States, and no flight plan had been filed. The pilot said that before landing, he received "computer weather information" and information from the destination airport's automated weather observing system. The preliminary accident report said that the pilot then told his passenger that he would "make one attempt at the crosswind landing and if he was unable to maintain the runway heading, they would divert."

The maximum demonstrated crosswind component for the accident airplane was 20 knots.

The report did not provide wind information for the destination airport but said at the time of the accident, winds at the closest weather-reporting facility, 20 statute miles (32 kilometers) east-southeast of the accident site, were from 170 degrees at 18 knots, gusting to 26 knots.

The pilot said that he "used half flaps for the landing approach and was maintaining the runway heading using full left rudder when a gust of wind moved the airplane left of the runway centerline." The pilot applied power, and the left wing struck the ground about 10 feet (three meters) left of the runway; the airplane's nose also struck the ground.

Section of Elevator Separates During Flight

Cessna 402C. Substantial damage. No injuries.

Visual meteorological conditions prevailed just after sunset for a flight in the United States. About 70 nautical miles (130 kilometers) north of the destination airport, the pilot began a 500-foot-per-minute descent at 185 knots.

About five nautical miles (nine kilometers) north of the airport, the airplane "pitched sharply nose down, with an uncontrollable back-and-forth oscillation of the control yoke," a preliminary report said. "A loud shearing noise was heard from the right rear of the aircraft before pitch control was regained. The oscillation lasted for about five seconds."

When the pilot looked to the rear of the airplane, he observed "sheet metal flapping in the wind near the elevator section," the report said. The pilot declared an emergency, extended the landing gear and flaps, slowed the airspeed and conducted a landing.

A preliminary examination revealed that about 16 inches (41 centimeters) of the right elevator's outboard area was missing. The missing section was found about five nautical miles north of the airport in a residential area.

The report said, "The remaining outboard of the elevator up to the inboard attaching hinge was peeled up and aft. The bolt connecting the elevator trim tab to the elevator trim actuator rod was missing."

Engine Fails During Aerobatic Maneuvers

North American P-51D-20 Mustang. Minor damage. No injuries.

Daytime visual meteorological conditions prevailed for the aerobatics display at an air show in England and for the flight to return the airplane to its home airstrip. As the pilot flew the airplane over the airstrip, he performed several aerobatic maneuvers. Then, while beginning a "moderately steep" climb from an altitude of less than 1,000 feet, the engine failed.

The pilot was unable to restore engine power, so he moved the propeller to "full coarse pitch" and landed the airplane in a field. He used his cellular telephone to call family members who had been watching from the airstrip and air show colleagues, who sent the crew of the air show's emergency-response helicopter to help the pilot.

The accident report said, "Circumstantial evidence suggests the engine power loss was caused by a short period of fuel starvation … probably caused by aerobatic maneuvering, momentarily uncovering the outlet in the left fuel tank, which was selected at the time."

Pilots of Fish-patrol Aircraft Land Safely After Collision

Cessna 185. Minor damage. No injuries.
Cessna 185. Minor damage. No injuries.

Daytime visual meteorological conditions prevailed for the flights of two float-equipped airplanes in Canada in support of different fishing operations. The pilot of one airplane was on a private business flight in support of company fishing vessels and was monitoring two radio frequencies. The pilot of the second airplane was conducting a charter flight for a government agency to observe herring spawn and was monitoring a different radio frequency.

The pilot of the charter airplane began a left turn to land near a boat operated by the government agency; he did not see the other airplane. The pilot of the private airplane saw the charter airplane too late to avoid the collision, which occurred 400 feet above the water. Both pilots maintained control of their airplanes; they established radio contact with each other, and each assessed the damage to the other airplane. They then landed the airplanes.

The accident report said that any of five radio frequencies would have been appropriate for pilots operating in the area, including the three frequencies being monitored by the two pilots.

"Risks associated with visual flight are well documented," the report said. "These risks are known to be mitigated by radio position reporting; such reporting requires aircraft to be on a common frequency. … Independent flight operations in the same area but operating on different frequencies increase the risks associated with visual flight."

Faulty Training Cited in Mishandling of Emergency

Eurocopter AS 350B3. Minor damage. No injuries.

The helicopter was being flown at 700 feet off the eastern coast of Canada for surveillance of a lobster-fishing dispute. As the pilot conducted a right turn, the red "GOV" (governor) warning light illuminated and the cockpit alarm sounded. The pilot continued the turn and headed toward the shore, where he planned a precautionary landing. He observed an increase in rotor revolutions per minute (rpm) above the limit and felt a severe rotor vibration.

"The pilot lowered the collective and reduced twist-grip throttle, but there was no apparent reduction in rotor rpm," the incident report said. "Believing that manual control of the throttle was lost, the pilot reopened the throttle to the 'FLIGHT' detent and tried to reach the overhead fuel-control mode-selector switch to move it to the manual position; however, the severe vibrations made it difficult to activate the caged switch."

The pilot then attempted to decrease main-rotor rpm by raising the collective, but there was no apparent change, and the helicopter continued its rapid descent. After landing, a severe ground resonance (destructive vibration induced by rotor-blade oscillation) developed; the pilot hovered the helicopter, but the vibrations continued, and he again landed the helicopter and activated the fuel shutoff lever on the ceiling to shut down the engine.

The report said that the pilot "had not received adequate flight training for the red 'GOV' light emergency and did not realize that the twist-grip throttle still controlled fuel flow to the engine. Consequently, the emergency was mishandled, resulting in a severe overspeed of the aircraft's dynamic components."

At the time of the incident, the operator required neither a pilot-proficiency check nor a pilot-competency check, and the operator was unaware that the pilot had received "less-than-adequate training" on the helicopter type, the report said.

After the incident, the operator issued a memorandum to its AS 350B3 pilots to discuss illumination of a red "GOV" light and changed the operations manual to show that helicopter pilots were required to have a proficiency check ride every two years and a route check in alternate years.

Helicopter Strikes Mountain on Flight in Clouds, Fog

Bell 206B JetRanger. Destroyed. Four fatalities.

The helicopter was being flown on a daytime heli-skiing flight in Switzerland and was transporting three passengers to a mountain glacier. The helicopter struck a mountain at 10,400 feet.

At the time of the accident, fog and low clouds prevailed in the area, with mountain peaks obscured.

Stuck-pedal Demonstration Ends in Rollover Accident

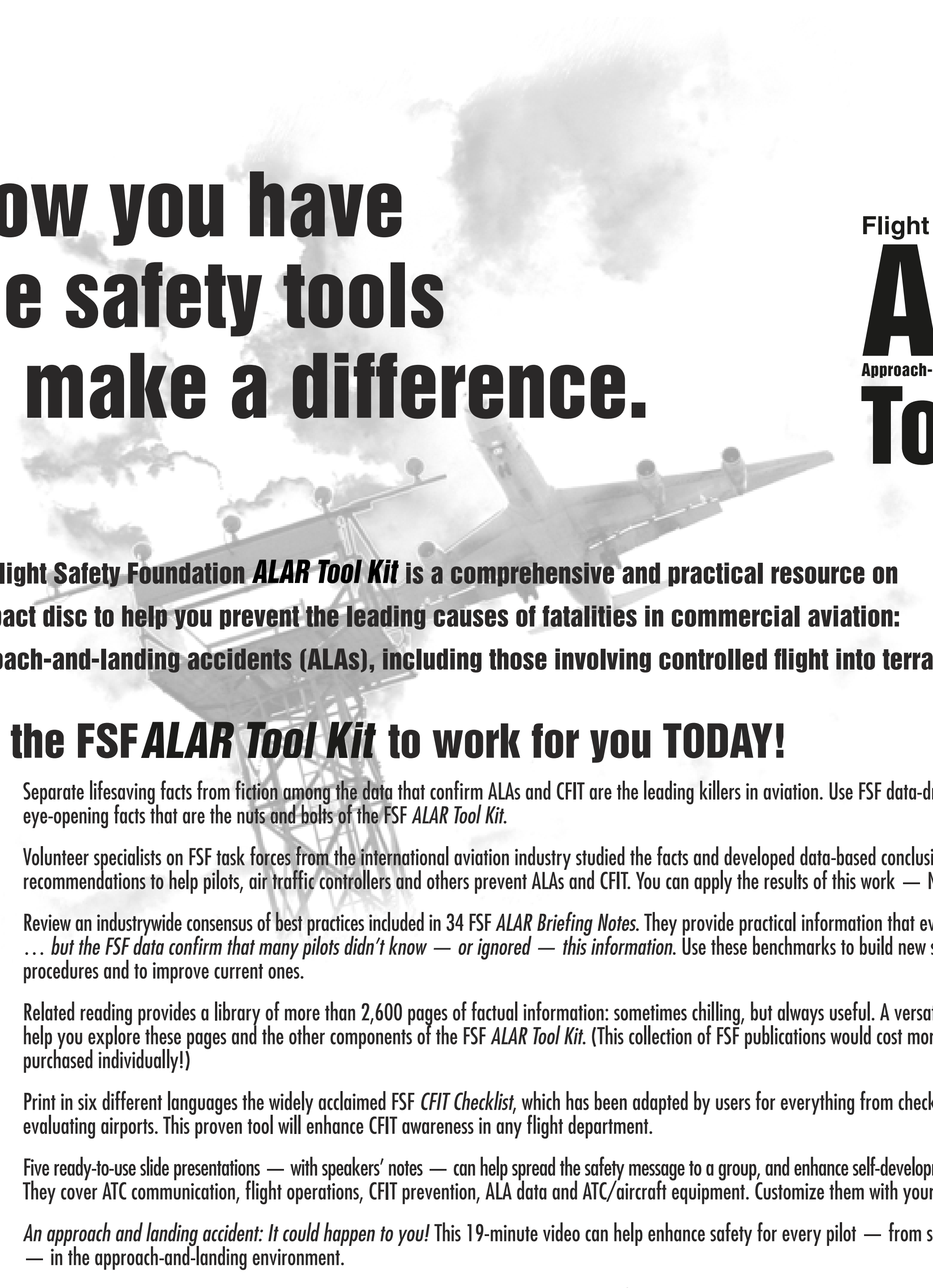
Robinson R22 Beta II. Minor damage. No injuries.

Visual meteorological conditions and calm winds prevailed for the instructional flight in South Africa. The instructor intended to demonstrate to the student what might happen if the right pedal were to become stuck while applying power during hover flight.

"The recovery technique involved raising the collective while simultaneously rolling off the throttle and reducing main[-rotor revolutions per minute (rpm)] and tail-rotor rpm to keep the helicopter aligned with the flight path," the accident report said. "The intention was to land the aircraft following the exercise; however, during the attempted landing, the left skid gear touched down first, positively, with slight lateral drift, which resulted in a rolling motion from which the instructor was unable to recover."

The main-rotor blades struck the ground, and the helicopter fell onto its left side.

The report said that the probable cause of the accident was that the instructor allowed the left-skid-first touchdown on an uneven surface and that he was unable to overcome the student's "strong reaction on the controls." ■



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