Flight Safety

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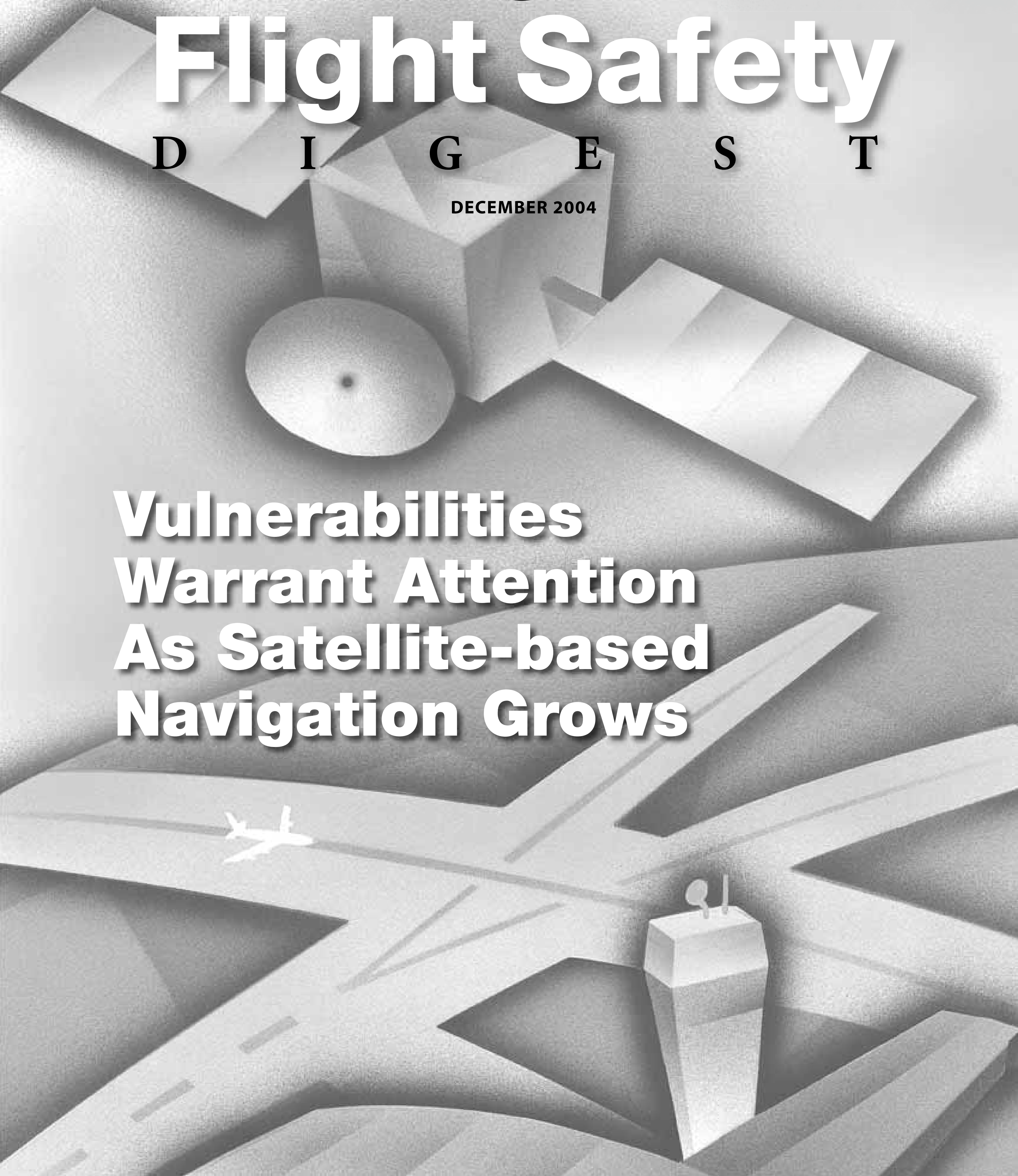

Vulnerabilities Warrant Attention As Satellite-based Navigation Grows

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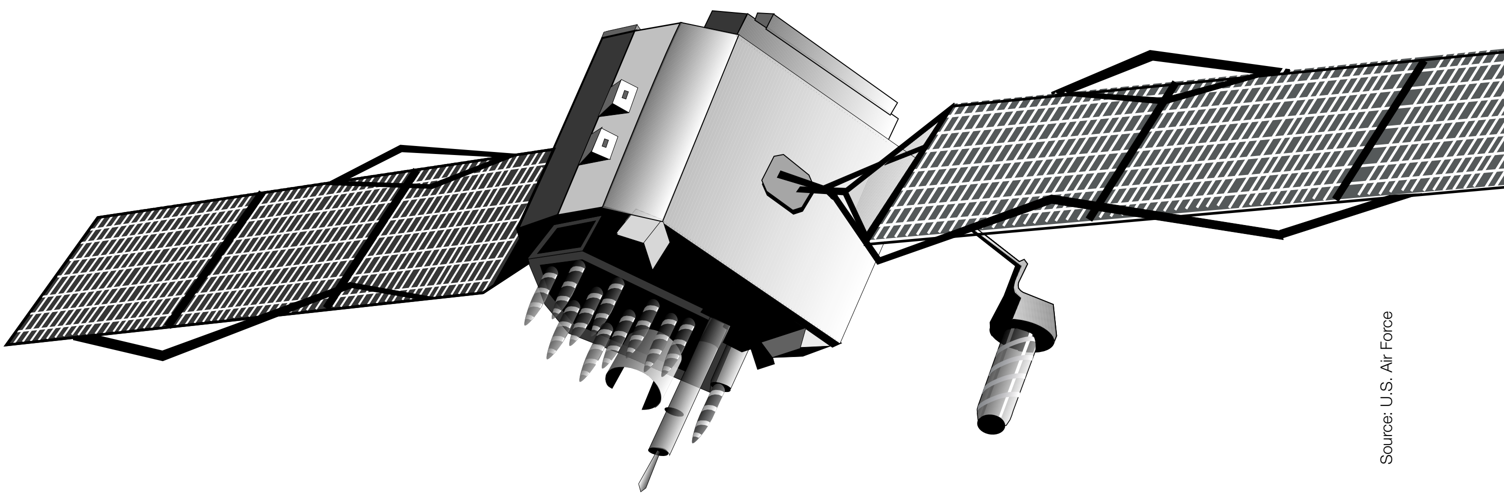
Vulnerabilities Warrant Attention as Satellite-based Navigation Grows

The International Civil Aviation Organization and other authorities recommend backup inertial-reference systems, ground-based navaids, and radar surveillance and vectoring to mitigate interference — unintentional and intentional — with navigation signals from space. Improved satellites and augmentation systems will help to lessen risks under instrument flight rules.

— FSF EDITORIAL STAFF



Source: U.S. Air Force

Civil aircraft operations are vulnerable to various types of radio frequency interference (RFI) that can disrupt navigation signals from the U.S. global positioning system (GPS) and could affect the evolving global navigation satellite system (GNSS). In recent reports — including a 2003 report for the International Civil Aviation Organization (ICAO)[1] and a 2004 report by the U.K. Civil Aviation Authority (CAA)[2] — researchers said that civil aviation authorities, aircraft operators and others should increase awareness about these vulnerabilities and prepare for disruptions that could occur during satellite-based navigation.

The GNSS currently comprises GPS and the Russian Federation's global navigation satellite system (GLONASS); both are undergoing improvements. The GNSS is scheduled to be expanded by the European Galileo satellite system, the U.S. GPS III[3] satellite system and satellite-based augmentation systems operated by Europe, India and Japan. (Separate from the GNSS, Beidou Navigation System [BNS], operated by the People's Republic of China since 2000, currently provides satellite-navigation signals for civil applications other than aviation within China.)

To comply with ICAO's required navigation performance specifications for operation under instrument flight rules (IFR), GPS must be used with a satellite-based augmentation system, a ground-based augmentation system or an aircraft-based augmentation system.

DOD has the authority to deny civil GPS service in specific geographic areas by jamming signals.

A satellite-based augmentation system improves GNSS integrity as well as accuracy and service availability, the U.K. CAA report said. Integrity is improved by the near-real-time broadcast of the operational status of the GNSS via a dedicated channel[4] (i.e., for an IFR-certified GPS receiver, from one second for a Category III precision approach to two minutes for oceanic operation). A ground-based augmentation system currently is required to conduct precision instrument approaches. An aircraft-based augmentation system uses navigation satellites as a data source with additional aids such as an inertial navigation system (INS), very-high-frequency omnidirectional radio (VOR), distance-measuring equipment (DME), LORAN-C, Omega, precise clock, radar or aerodynamic/thermodynamic sensors (e.g., airspeed and altitude), the report said.

In October 1997, the President's Commission on Critical Infrastructure recommended a reassessment of the U.S. government's plans for use of GPS in the transportation sector. Subsequently, various studies were conducted to address concerns about related capabilities and vulnerabilities. The ICAO report and the U.K. CAA report have reiterated many of the findings and recommendations of these studies.

In the United States, the Federal Aviation Administration (FAA) will maintain sufficient navigation aids (navaids) with VOR, DME, instrument landing system (ILS) and nondirectional beacons (NDBs) to support en route navigation and instrument approach operations in the event of disruption of GPS service, which is supplemented by the wide-area augmentation system (WAAS).[5] As of November 2004, GPS had 30 satellites[6] in its constellation with 24 satellites nominally used to provide civil signals worldwide. Operated by the U.S. Department of Defense (DOD), GPS also broadcasts encrypted signals for military applications.

DOD has the authority to deny civil GPS service in specific geographic areas by jamming signals[7] — emitting powerful radio frequency energy — without degrading/denying GPS reception elsewhere. Moreover, DOD routinely tests navigation-warfare methods, which also can affect temporarily civil use of GPS in specific geographic areas. The U.S. Department of Transportation (DOT) provides advance notice about such intentional service outages and/or temporary GPS unreliability via GPS/WAAS notices to airmen (NOTAMs).

Civil aviation authorities in several other countries and regions — for example, Australia, Europe (European Organization for the Safety of Air Navigation [Eurocontrol]) and Germany — also have implemented publicly accessible GPS-outage prediction systems that enable pilots and air traffic controllers to take appropriate actions for outages that may affect their operations.[8]

To meet ICAO requirements in Europe for user-level integrity monitoring, European augmentation systems will be used (initially, GPS will be supplemented with the European Geostationary Navigation Overlay Service [EGNOS][9] and, at a later date, GPS and Galileo will be supplemented with EGNOS). Galileo is scheduled to be operational in 2008 and will be interoperable with GPS and GLONASS for civil aviation. Moreover, India plans to provide satellite augmentation for Indian airspace, including Indian oceanic airspace, and for large parts of the Asia Pacific Region, and Japan plans to provide satellite augmentation throughout the Asia Pacific Region.

Airborne Alerts of GPS Unreliability Essential to Pilots

"With respect to integrity (as the parameter most directly related to safety) a potential safety hazard (i.e., a loss of integrity) can happen in one of two ways," said the U.K. CAA report. "Either an unsafe condition is not detected, or it is detected but the alert is not received by the pilot within the required time-to-alert. … Operational level failures [include] intended signal interference, unintended signal interference and sudden changes in the signal-propagation properties within the [ionosphere]."[10]

The effect on integrity — when comparing ground-based navaids with GPS — involved studying differences in how quickly sources outside the aircraft alert pilots to navigation anomalies.

"[VOR ground facilities] use an independent monitor to supply system integrity and remove a signal from use within 10 seconds of an out-of-tolerance condition," the U.K. CAA report said. "Integral monitors in [ILS] and [microwave landing system (MLS)] facilities exclude anomalous signals from use within one second. … Although the GPS … satellites themselves provide a reasonable level of integrity, anomalies could go undetected for too long a period [of time]. It typically takes the [DOD] five [minutes] to 15 minutes to remove a satellite with a detected anomaly from service. … The main approaches to the monitoring of integrity of satellite-based navigation systems are external monitoring [and] receiver autonomous integrity monitoring (RAIM)."

RAIM calculations are incorporated into a GPS receiver to independently establish system integrity by detecting the existence of an erroneous measurement and by identifying the affected satellite; both of these RAIM capabilities are required to use GPS as the primary means of airborne navigation. The RAIM functions of GPS receivers certified for IFR aircraft navigation are considered to be effective in detecting excessive position errors, whether they result from unintentional interference or the methods of intentional interference that have been studied.[11]

"The FAA [and] international counterparts have focused on how to accomplish integrity monitoring for safety-of-life [GPS] services through the use of [RAIM], wide-area [augmentation systems such as WAAS, which was approved for WAAS-specific instrument approaches in July 2003; Figure 1, page 4][12] and local-area augmentation systems [such as LAAS]," a team of U.S. researchers said in 2004. "Integrity is a measure of the trust which can be placed in the correctness of the information provided by the total system. Integrity includes the ability of the system to provide timely and valid warnings to the user (alerts) when the system must not be used for the intended operation."[13]

Guidance to pilots about the authorized uses of GPS under IFR (and air carrier operations specifications) emphasizes the importance of RAIM. FAA's *Aeronautical Information Manual (AIM),* for example, said that RAIM requires a minimum of five GPS satellites "in view," or four satellites and input from a barometric altimeter (baro-aiding), to verify GPS integrity. Six satellites in view, or five satellites plus baro-aiding, are required to isolate a corrupt satellite signal and remove it from the GPS receiver's navigation solution.

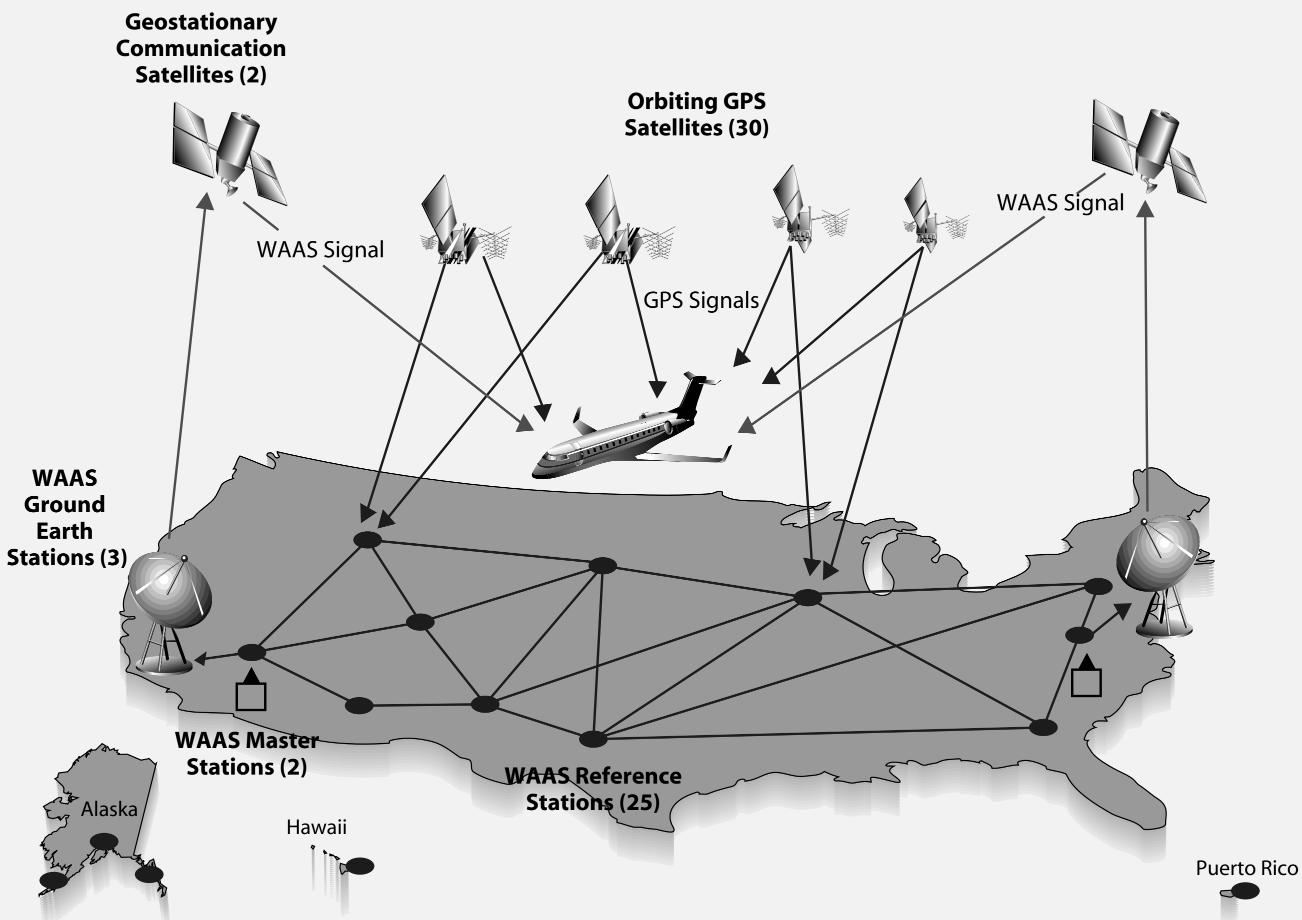
"Without RAIM capability, the pilot has no assurance of the accuracy of the GPS position," the *AIM* said. "Aircraft using GPS navigation equipment under IFR must be equipped with an approved and operational alternate means of navigation appropriate to the flight. Active monitoring of alternative navigation equipment is not required if the GPS receiver uses RAIM for integrity monitoring. Active monitoring of an alternate means of navigation is required when the RAIM capability is lost. Procedures must be established for use in the event that the loss of RAIM capability is predicted to occur. In situations where this is encountered, the flight must rely on other approved equipment, delay departure or cancel the flight. … If GPS avionics become inoperative, the pilot should advise [air traffic control (ATC)] and amend the equipment suffix [of the flight plan]."

Ground-based navaids allow pilots of aircraft equipped with inertial-reference unit (IRU) and flight management computer (FMC) avionics to continue en route navigation using dual DME-position updates to the FMC or procedures based directly on VOR and DME guidance if GPS avionics become inoperative. Aircraft without IRU/FMC capabilities would proceed to a VOR and conduct an approach and landing, but not necessarily at the planned destination airport, FAA said.[14] (The accuracy of a DME/DME position solution depends on the angle between the selected navaids from the position of the aircraft; therefore, analysis is required of available navaids on routes flown, including the added effect of widespread instrument meteorological conditions (IMC) on those routes. Similarly, operators of aircraft limited to low-altitude operations must consider whether complete VOR en route coverage would be available during a GPS outage.)

"Modern transport category turbojet aircraft [with IRU/FMC

"Without RAIM capability, the pilot has no assurance of the accuracy of the GPS position."

Figure 1
Current Global Positioning System With Wide Area Augmentation System in the United States[1]



GPS = Global positioning system WAAS = Wide area augmentation system

[1] WAAS was approved for instrument flight rules operations in the continental United States and Alaska, from the surface to 100,000 feet, effective July 10, 2003.

Source: U.S. Federal Aviation Administration

equipment], when engaged in relatively stable en route flight, may be able to continue navigating safely an hour or more after losing radionavigation position updating," FAA said. "In some cases, this capability may prove adequate to depart an area with [a] localized [GPS outage] or proceed under visual flight rules [VFR] during good visibility and high ceilings. However, IRU performance without radionavigation updates degrades substantially faster on a maneuvering aircraft, and the viability of continued terminal-area navigation is unclear.

"There is no assurance of compliance with airspace requirements after executing a procedural turn or entering a holding pattern, even in en route airspace. … Aircraft equipped with either IRU/FMC using DME updates (assuming a network of VOR/DME navaids) or integrated GPS/inertial [or LORAN-C] would be able to continue en route through nonprecision approach operations in the affected area of a GPS disruption."

ATC would vector aircraft that do not have IRU/FMC to an airport outside the area of the GPS outage or to an airport with visual meteorological conditions (VMC).

"Aircraft with a VOR [receiver] (assuming a network of VOR/DME navaids) may need to be vectored into an area with VOR coverage, to an airport that has an instrument approach defined using VOR, to an airport outside the affected … area, or to an airport in VMC," FAA said. "Additional navaids may be needed to assure the provision of course guidance for missed approaches and departures (where required), and where terrain [clearances] or obstruction clearances must be maintained — particularly in non-radar environments."

Effects of GPS Outage May Vary by Duration

FAA has said that some of the safety effects of a GPS outage can be envisioned using two assumptions: that GPS is the sole means of aircraft navigation and that it has been disrupted. This "what if" method may help flight operations specialists to develop scenarios relevant to their actual operations, in which backup navigation equipment and procedures normally would be available to the flight crew.[15]

Backup procedures and/or systems for GPS outage may involve the following issues, FAA said:

- "Loss of approach [guidance] and missed-approach guidance during the landing phase of navigation is critical in those cases where procedural missed-approach instructions (e.g., climb [on] runway heading, turn left at 2,000 feet to heading 350) cannot be used in non-radar environments, or in cases where terrain, obstructions or other operations require course guidance. In the case where procedures can be followed but the destination of the missed approach is a waypoint, the procedure would need to be modified. The loss of navigation during landing and missed-approach phases in [IMC] would require [ATC] support, which leads to workload increases;

- "A significant workload increase in itself would not lead directly to an accident. However, procedures and training would be required to deal with the loss of navigation and to assure that pilots and air traffic controllers are equipped to cope with sudden navigation outages affecting all aircraft in the airspace. [Secondary surveillance radar provides the backup method where automatic dependent surveillance–broadcast (ADS-B, which is dependent on GPS signals) is used to separate aircraft in lieu of radar; if unavailable, operators must revert to VFR operations.] The burden in the cockpit would depend upon the phase of operation. In the en route environment, the pilot … would quickly become dependent on the controller for radar vectors. If in a non-radar environment, the pilot workload could become unacceptable. [In a radar environment,] the challenge for the controller would be to quickly identify areas unaffected by the [GPS-signal] disruption and to provide radar vectors to guide the aircraft to these areas, to a suitable alternate airport, or to [VMC]. In the absence of a holding capability based on the aircraft's own navigation, there would be no tactical safety valve to regulate demand;

- "The absence of a holding capability would remove from the controller the ability to add order to chaos, i.e., to sequence aircraft for landing in a reduced-capacity scenario, to deal with crossing-traffic conflicts, and to provide a means to manage demand and retain safety. Holding in absence of any course guidance, while possible, is unacceptable in cases of medium [traffic density] to high traffic density; [and,]

- "Course guidance is critical for low-altitude en route navigation and for missed approaches and departures where terrain [clearances] or obstruction clearances must be maintained. In non-radar environments, the pilot is responsible for maintaining clearance from terrain and obstacles. During an outage, the pilot could not continue on the planned flight path. If the aircraft were under radar control, the air traffic controller would need to provide terrain-and-obstruction clearance. Some airport missed-approach procedures in mountainous terrain would need to be modified significantly to provide procedural missed approaches; this would not be possible in all cases."

A 2001 report by the John A. Volpe National Transportation Systems Center of DOT said that in civil aviation, disruption caused by degradation or loss of the GPS signal conceivably might have the following effects:[18]

> **"The absence of a holding capability would remove from the controller the ability to add order to chaos."**

"A small level of noise in the GPS band can disrupt reception over tens or even hundreds of miles."

- "The impacts of *momentary* outages [i.e., one outage lasting from a few seconds to a minute over a confined region] would be minimal, assuming there is timely detection of the outages and alerting of the flight crew and air traffic controllers. However, this type of outage could result in missed approaches being required for aircraft [flight crews conducting] nonprecision [approaches] or precision approaches, thus having an operational impact. When operating over certain terrain, the loss of missed-approach guidance could be hazardous;
- "The duration of [*serious*] outages [i.e., one outage lasting from a minute to a few hours over a confined region] inevitably will require that an alternate procedure, possibly a backup system, be utilized for any of the flight [phases]. … The aviation community should continue to develop an appropriate mix of proven backup systems and procedures to mitigate the serious GPS outage. For shorter flight segments, such as en route [navigation] or terminal navigation, loss of GPS even for a short period of time could require extensive rerouting and vectoring of aircraft; [and,]
- "A safety impact might occur [during a *severe* outage, i.e., one outage over a wide area lasting for days or a series of shorter outages over a wide area] if extensive vectoring of aircraft to other airports results in excessive controller workload, considerable pilot confusion and additional workload, and possibly even fuel depletion if nearby airports were not available with weather conditions that would permit visual approaches and landings. … For a severe outage, aircraft [flight crews] would no longer be authorized to take off and conduct operations under [IFR]."

Certification, Procedures Address On-board GPS-signal Interference

"It is well known that the GPS signal is very weak [10^{-16} watt at Earth's surface], and, assuming a standard GPS receiver, a small level of noise in the GPS band can disrupt reception over tens or even hundreds of miles," researchers for The Johns Hopkins University said in a 1999 report.[16]

Receiver installation/integration/certification and operator procedures restricting the use of portable electronic devices (PEDs) protect aircraft from on-board interference sources. Antenna design, signal processing advances and integration of data from other navigation aids/sources are also effective against interference.

"Transmissions from on-board [very-high-frequency (VHF)] communications equipment have caused significant interference with GPS-signal reception," the Volpe report said. "However, this can be managed during GPS installation through the use of an appropriate in-line filter at the transceiver antenna connector. … PEDs [including] cellular telephones and two-way pagers … can cause disruption of GPS-signal reception [aboard the aircraft]."

Many environmental factors also affect the probability that unintentional interference could occur.

The 2003 ICAO report said, "The likelihood of unintentional interference is often a function of geography. Large cities with significant … interference sources, industrial sites, etc., are more prone to the unintentional interference than remote regions. … Ground-based sources of [unintentional] interference include mobile and fixed VHF communications, point-to-point radio links operating in the GNSS frequency band, harmonics [frequencies that are integral multiples of the fundamental ultra-high-frequency (UHF) frequency, which may interfere with a fundamental GPS frequency] of television stations, [some] radar systems, mobile satellite communication systems and military [radar/communication] systems. … Rapid and large changes in the ionosphere are frequently observed near the geomagnetic equator, but their effect is not large enough to impact en route [operations] through nonprecision-approach operations. For approaches with vertical guidance and precision-approach operations, the effects of these changes can be assessed and mitigated when designing [GNSS] augmentation systems."

Researchers for DOT in 1999 had said that UHF analog broadcast television was determined to be the greatest threat among potential off-aircraft interference sources because of factors such as high radiated-power levels and frequency interference.[17]

"The risk due to television-broadcast harmonics … is 'reasonably probable' en route, but the impact is no effect because of the short duration of any outage," the Johns Hopkins report said. "Thus, the television-broadcast risk is acceptable for en route operations. In the terminal area, the impact was judged as 'major' [i.e., a significant failure condition that would reduce safety margins or functional capabilities of an airplane, or increase crew workload or conditions impairing crew efficiency] because of the significant outages that could occur. … Recommended mitigations, however, would make this risk acceptable."

The severity of effects that could be caused by a GNSS outage depends on the following factors, said the ICAO report:

- Airspace affected (i.e., a rapid response by the flight crew typically would be more critical for a terminal area than for high-altitude en route operations, although en route separation minimums also may be a critical factor);
- Density of air traffic (i.e., "in regions with high traffic density, reliance on radar vectoring or pilot procedures may be impractical due to workload");
- Service level required;
- Availability of alternate navigation methods;
- Availability of radar vectoring for separation and navigation to alternate airports if required;
- Duration of the outage;
- Geographic extent of the outage;
- Capability of the air traffic service provider to rapidly analyze the outage;
- Weather conditions; and,
- Indirect effects on flight operations, including disruption of satellite-based precision-timing signals required by ground computer networks, such as those used for ATC communications, digital radar systems and GNSS augmentation.

The U.S. GPS modernization program — scheduled to include greater GPS-signal power and civil use of two additional frequencies — is expected to substantially reduce GPS-signal vulnerability to unintentional interference and to accomplish "some degree of threat reduction from intentional interference," the Volpe report said. Nevertheless, civil GPS receivers that use only the current civil frequency are expected to remain in wide use by aircraft operators beyond 2010.

"The use of stronger signals and diverse frequencies planned for GPS, GLONASS and Galileo will effectively eliminate the risk of unintentional interference, since it is highly unlikely that such an interference source would simultaneously affect more than one frequency," the ICAO report said. "GPS, GLONASS and Galileo will offer independently operated satellite constellations and independent signals. Thus, GNSS service failures, when a combination of constellations is implemented, will be extremely unlikely. … To date, no vulnerabilities have been identified that could not be addressed by appropriate mitigation methods, thus confirming the ultimate goal to transition to GNSS as a global system for all phases of flight."

No Reports of Intentional Jamming, But Threat Remains

In the various reports, researchers have differed in their characterizations of the potential vulnerabilities of civil aviation to GPS interference. Although there have been no recorded events of "intentional jamming directed at civil aircraft" (as of October 2003), the ICAO report said that the possibility of intentional interference must be considered and evaluated as a threat.

"In recent years, the potential for intentional, malicious disruption of GPS has been recognized," said the Volpe report.

> **"No vulnerabilities have been identified that could not be addressed by appropriate mitigation methods."**

The currently weak civil GPS signal, open access to its technical specifications and absence of encryption have been cited as reasons for the susceptibility to jamming. In recent years, GNSS specialists have studied the possibility of "spoofing" — intentional broadcast of phantom GPS-satellite signals to significantly increase a receiver's navigation error in an undetectable manner.

"[Jamming] is either realized as emission of a signal close to the GPS spectrum or, if more sophisticated, as emission of a GPS-like signal," the 2004 U.K. CAA report said. "Civil receivers are vulnerable. This could prevent GPS receivers from tracking the signal or cause frequent loss-of-lock (positioning error up to 600 meters [1,969 feet]). Sophisticated jamming could prevent a receiver from acquiring the signal."

In practical terms, signals reaching the GPS antenna on top of an aircraft in flight — from jamming devices on the ground — would be decreased and/or blocked to some degree by the fuselage. Moreover, terrain masking (blockage of signals by buildings, mountains and other objects) limits the effectiveness of a jamming device on the ground. Nevertheless, researchers assume that the GPS civil signals could be denied to any aircraft along the approach-and-landing trajectory by a jamming device that is either suitably sited on the ground or airborne.

Conceivable perpetrators could be "individuals or small groups ('hackers') who seek to create a nuisance by exploitation of a technological weakness or … a hostile organization or government that views the reliance by civil aviation on GPS as an opportunity for terrorist actions," the Johns Hopkins report said. "It is the conclusion of this study that the latter source of interference [terrorism] is improbable because of the lack of incentive given the very low safety risk. The hacker, on the other hand, may be satisfied with the more limited nuisance that is created. … [Components required to build a] 100-watt jammer would cost approximately US$300 and [it would be] about the size of a shoe box, while [those for] a 1,000-watt jammer would cost approximately $3,000 and [it would be] about the size of a small suitcase."

"A modest level of jamming power can essentially stop GPS operations within a large area surrounding an airport."

In 2003, the technical description and circuit specifications for a low-cost jamming device were published on an Internet site.[19] The unidentified author said that this information was published so that the "typical citizen" would have access to self-defense methods against a proliferation of "hidden" GPS-tracking devices — but the author did not mention the possible risk to safety-of-life GPS applications such as aircraft navigation.

"A modest level of jamming power can essentially stop GPS operations within a large area surrounding an airport," the Johns Hopkins report said. "The result would be simultaneous loss of [GPS] navigation by all aircraft and, therefore, a substantial increase in workload and a possible compromise of safety. … It was judged that the occurrence of widespread GPS outage caused by intentional interference does not pose any direct safety risk because no flight operation is wholly dependent on GPS navigation. For example, if we consider the most critical case of a Category III precision approach, a sudden loss of GPS signal would be known to the navigation system and might necessitate an abort [go-around], or in the final critical moments, use of the altimeter and possibly an [IMU]. Thus, GPS outage because of jamming could have continuity impact, but loss of integrity is not an issue because accuracy degradation is relatively small before the signal is completely lost. The only possible risk to safety would result if the [ATC] system were not able to accommodate the disruption caused by interference. However, with validated procedures and proper training, this risk should be manageable."

A low-power jammer (i.e., one watt) that is airborne or a low-power jammer that generates a GPS-like signal can deny GPS tracking to an already-locked receiver or prevent the receiver from locking on GPS signals. Similarly powered spoofing devices also can cause failure of GPS signal acquisition. In various scenarios, such devices could affect receivers as far away as 998 kilometers (539 nautical miles).

"[GPS-like interference] … will be extremely difficult to detect by conventional methods such as spectrum analysis," the Volpe report said. "The most disturbing reports on the effect of jamming involve inaccurate position determination provided by receivers under jamming. Several tests of GPS receivers, aviation-certified and uncertified, have shown that jamming can introduce large range errors. This range distortion usually occurs just before loss of lock, and the receiver tracking flag (if present) may not indicate a problem. … These anomalies are not due to GPS deficiencies but to receiver-design limitations."

In 2003, an Australian research team said that wide-band noise jamming represents the most affordable, feasible and tactically effective GPS-jamming technique that is likely to be encountered in the near term.[20]

"Any technically minded person can locate wide-band jamming circuits that match the GPS [frequencies published on the Internet] and build them," the Australian report said. "Relatively small, low-power, unsophisticated noise jammers hold the potential to significantly disrupt or deny GPS operation, particularly with the [civil signal] code receiver. Since these jammers are based on simple technology, they may [be] tactically feasible to field in large numbers. A large matrix of such jammers could create a GPS-denial zone with dimensions of hundreds of kilometers."

Hypothetical effects of spoofing in civil aviation also have been discussed widely, although some disagreement exists about its likelihood to threaten GPS integrity.

"The study concludes that there is no credible spoofing threat and that, although real, jamming threats can be managed," the Johns Hopkins report said in 1999, drawing a distinction between intelligence about specific GPS-related threats and their technological feasibility. "The only possible threat to integrity is spoofing … but this would require considerably greater expense and effort [than jamming]. … Intentional interference is by far the greatest risk area; however, the [future] avionics [will be] designed to quickly recognize the onset of this threat.

"Assuming that sufficient resources are available to vector aircraft away from jammed regions, this threat will pose no safety risk. It can, however, create considerable disruption in [ATC] and flight schedules. Methods to detect, locate and prosecute those who intentionally jam GPS signals must be put in place to discourage such activities. [ATC] procedures must also be established to manage affected aircraft."

Two years later, the ICAO report echoed the conclusions that jamming can be managed and that spoofing is not considered a likely threat.

"Intentional interference is by far the greatest risk area."

"While spoofing can theoretically cause misleading navigation for a particular aircraft, it is very likely to be detected through normal procedures (e.g., by monitoring of flight path and distance to waypoints and by radar surveillance)," the ICAO report said. "In view of the difficulty of spoofing GNSS, and the fact that unique operational mitigations are not deemed necessary, spoofing is not further addressed in this [report]."

Nevertheless, other researchers continued to identify spoofing of the GPS civil signal as an important focus of continuing countermeasures research.

"The Vulnerability Assessment Team at Los Alamos [New Mexico, U.S.] National Laboratory has demonstrated the ease with which *civilian* GPS spoofing attacks can be implemented," one U.S. group said in a 2003 report. "This spoofing is most easily accomplished by using a GPS satellite simulator. Such simulators are uncontrolled [easily acquired] and widely available."[21]

Commercial GNSS signal simulators enable legitimate evaluation of receivers by engineers, manufacturers, military/security specialists and regulators with software tools and/or by generating artificial radio frequency signals in space. They are used inside offices, laboratories or manufacturing facilities without affecting the users of genuine satellite signals, or in open-air experiments with prior official approval and notification of users (such as by NOTAMs that describe the geographic area and time period in which GPS/WAAS will be unreliable).[22]

Denial spoofing and deceptive spoofing are two intentional-interference types of greatest concern, said the Australian report.

"With denial spoofing, a GPS-similar waveform is transmitted in an attempt to prevent a GPS receiver from tracking real GPS satellite signals," the Australian report said. "Deceptive spoofing involves transmitting a similar waveform, but it attempts to deceive the GPS receiver into believing the spoof signals are actual GPS satellite signals. … The possibility of terrorist organization[s] or states employing [a] commercially available GPS-constellation simulator for spoofing is very real."

The Volpe report's recommendations about mitigation of intentional interference with GPS signals included continuing assessment of how to apply military anti-jam technology, including receivers and antennas, to civil aircraft; providing appropriate methods of detecting spoofing in civil safety-critical GPS receivers; providing military anti-spoofing technologies for use by civil aircraft; continuing threat analysis by transportation-security specialists; and advising the civil aviation community of elevated threats and countermeasures to the extent possible within the limits of security requirements.

"Unfortunately, given the potential risk, little publicly available information or test results exist concerning the response of commercial [civil GPS] receivers to spoofing," the Volpe report said. "The sparse unclassified literature on anti-spoof simulation and testing indicates that much development and testing remains to be done in order to determine the most effective anti-spoofing technique.

"On the other hand, spoofing signals may have characteristics that will someday allow the user to detect and ignore them. Unlike random noise [in jamming], it employs a known signal that is very structured. … The spoofing signal will as a rule differ in some respect from the true GPS signal. It can differ in time of arrival, Doppler shift, amplitude, polarization or angle of arrival. These differences, if exploited, can be used to ignore the spoofers and concentrate on the valid GPS signals."

"Interference-detection systems may be implemented in aircraft and on the ground."

Pilot Reporting Creates First Line of Defense

"The ability to locate the interferer and terminate the interference to GNSS without delay is a critical aspect," the ICAO report said. "The primary method of detecting interference is through pilot reporting. As many aircraft may experience outage simultaneously when interference first occurs, an automated method of reporting the outage (e.g., an automatic data-link message) would reduce workload and facilitate defining the outage area and locating the interferer. Interference-detection systems may be implemented in aircraft and on the ground."

A similar conclusion of the Johns Hopkins study was that if many flight crews raise the alert about GPS anomalies, during any phase of flight operations, ATC (or other designated authority) should recognize immediately the possibility of a jamming/spoofing scenario (in the absence of another explanation from DOD) and airborne detection-enforcement personnel should be deployed.

"To take advantage of anomalies detected by the public, the FAA has created a GPS interference-tracking database," DOT researchers said in a 1999 report.[23] "The [U.S.] Coast Guard Navigation Center and the [U.S.] Air Force Space Command maintain similar databases, and a data-transfer capability among the three has been implemented. … The FAA database will be analyzed with the intent that the cause of even small-but-recurring incidents (restricted in duration and geographical area) be determined. [Other FAA steps to reduce the effects of GPS interference incidents] include establishment of an agency-wide coordinated program of fielding RFI localization equipment and development of [tactical air] traffic management procedures … [with goals] to detect and localize an RFI source near a major hub [airport] in real time and to eliminate the source in near real time."

Continuing education enables pilots and air traffic controllers to remain current on GNSS-related human factors, limitations and vulnerabilities, including issues such as crew over-reliance on GNSS-based navigation and safety risks in troubleshooting failing GPS performance during a critical flight phase.

Civil aviation authorities worldwide are expected to consider the vulnerability of GNSS in decisions about installing, modifying or decommissioning ground-based navaids, the ICAO report said. Aircraft operators similarly can assess their backup avionics, procedures and training — looking at factors such as geographic location, types of flight operations and political threats — to decide what level of mitigation strategy is appropriate.■

Notes

1. International Civil Aviation Organization (ICAO). *Report of the Eleventh Air Navigation Conference, Montreal, 22 September to 3 October 2003.* Appendix A, "Guidelines on [Global Navigation Satellite System (GNSS)] Vulnerability and Mitigation Methods Including Terrestrial, Airborne and Procedural Solutions." Feb. 10, 2003.
2. U.K. Civil Aviation Authority (CAA). *GPS [Global Positioning System] Integrity and Potential Impact on Aviation Safety.* CAA Paper 2003/9. April 2004.
3. U.K. CAA. The report said, in part, "There are plans to modernize GPS under the GPS III program in order to provide improved capabilities to fully support safety-critical applications such as aviation. The first GPS III satellite is to be launched in 2009 with an eventual 30-satellite constellation. The program is currently in the requirements-definition phase [and preliminary design phase] and is expected to be fully operational in 2020."
4. "Near real time" means communication within the time-to-alert, which the U.K. CAA report defined as "the maximum time allowed from the moment a fault resulting in an unsafe condition is detected to the moment that the user is made aware of it."
5. John A. Volpe National Transportation Systems Center, U.S. Department of Transportation (DOT). *Vulnerability Assessment of the Transportation Infrastructure Relying on the Global Positioning System.* Aug. 29, 2001. The Volpe report said, "The wide-area augmentation system (WAAS) is [a supplement] to GPS that determines GPS integrity and differential correction data on the ground through a network of monitor stations and a central processing facility. It then uses geostationary satellites [positioned over the United States] to broadcast integrity messages and differential corrections, as well as a ranging signal, to the aircraft on the GPS [civil] signal. … The local-area augmentation system (LAAS) is another [supplement] to GPS which will be used [later in this decade] to support terminal-area navigation and Category I through Category III precision approach operations. The LAAS ground system consists of multiple reference antennas/receivers at an airport, a processing station, [very-high-frequency (VHF)] data-broadcast equipment and, optionally, ground-based pseudolites [devices that broadcast satellite-like signals from one or more locations at an airport]. The GPS signals received by the multiple reference/monitoring antennas are processed to obtain the differential correction and integrity information, which is then broadcast to the aircraft via the VHF data link."
6. The Associated Press. Untitled article, Nov. 6, 2004. Boeing Integrated Defense Systems. "Boeing Delta II Adds Another GPS Satellite to Air Force Constellation." News release, Nov. 6, 2004.
7. U.S. Department of Defense and DOT. *2001 Federal Radionavigation Plan.* Document DOT–VNYSC–RSPA–01–3. This document contains the following terms related to intentional radio frequency interference: *Electromagnetic interference* means "any electromagnetic disturbance that interrupts, obstructs or otherwise degrades or limits the performance of user equipment." *Electromagnetic jamming* means "the deliberate radiation, reradiation or reflection of electromagnetic energy for the purpose of preventing or reducing the effective use of a signal." *Electromagnetic deception* means "deliberate radiation, reradiation, alternation, suppression, absorption, denial, enhancement or reflection of electromagnetic spectrum in any manner intended to convey misleading information." *Electromagnetic intrusion* means "intentional insertion of electromagnetic energy into transmission paths with the objective to deceive or confuse the user."
8. Parmet, Jon; Rossetti, Jayne; Van Dyke, Karen. *Development of Global Positioning System Prediction Tools to Support Flight Planning.* John A. Volpe National Transportation Systems Center, DOT. <www.volpe.dot.gov> April 29, 2004.
9. ICAO. *Report of the Eleventh Air Navigation Conference.* Remarks by M. Ayral, European Community. Europe plans to implement a space-based augmentation system for GPS and the global navigation satellite system (GLONASS) called the European Geostationary Navigation Overlay Service (EGNOS) in 2004 and has under development the civil global navigation system called Galileo. Remarks by A. Neradko, Russian Federation. The Russian Federation currently has a program to restore the orbital segment of GLONASS to 24 satellites with second-generation GLONASS-M satellites and gradually to introduce third-generation GLONASS-K satellites, which will radiate navigation signals using three frequencies. Remarks by T. Iwasaki, Japan. Japan has announced plans to implement the Multi-functional Transport Satellite (MTSAT) with capabilities including augmentation of GNSS using two satellites scheduled for launch in 2004 and 2005. India has announced plans to implement the GPS and GEO [geostationary] Augmented Navigation (GAGAN) system for augmentation of GNSS in three phases that begin in 2005.

10. DOT said, "The ionosphere [part of the atmosphere] surrounding the Earth at approximately 350 kilometers [217 statute miles or 1.1 million feet] … can refract the … signals of GPS. This effect is called scintillation."

11. Volpe.

12. Hanlon, Dan. "FAA Global Navigation Satellite Systems (GNSS) Programs Update." FAA Air Traffic Organization. <gps.faa.gov>.

13. Van Dyke, Karen; Kovach, Karl; Lavrakas, John; Carroll, Brian. "Status Update on GPS Integrity Failure Modes and Effects Analysis." Paper presented during the National Technical Meeting of the Institute of Navigation (ION), San Diego, California, U.S., Jan. 26–28, 2004.

14. FAA Architecture and System Engineering Directorate. *Redundant Radionavigation Service in the National Airspace System: An Analysis of Needs and an Assessment of Alternatives Beyond 2010.* October 1998.

15. FAA Architecture and System Engineering Directorate.

16. Applied Physics Laboratory, The Johns Hopkins University. *GPS Risk Assessment Study Final Report.* Version M8A01 Revised. January 1999.

17. Geyer, Michael; Frazier, Robert. "FAA GPS RFI Mitigation Program." A paper presented to the ION GPS '99 conference in Nashville, Tennessee, U.S., Sept. 14–17, 1999.

18. Volpe Center.

19. Brewin, Bob. "Homemade GPS jammers raise concerns." *Computerworld.* Jan. 17, 2003.

20. Spencer, T.A.; Walker, R.A. "Prediction and analysis of GPS susceptibility to multipath and spoofing interference for land and space applications." Paper presented at SatNav 2003, the 6th International Symposium on Satellite Navigation Technology Including Mobile Positioning and Location Services, Melbourne, Australia, July 22–25, 2003.

21. Warner, Jon S.; Johnston, Roger G. "GPS Spoofing Countermeasures." Paper LAUR–03–6163, published by the Vulnerability Assessment Team, Los Alamos National Laboratory, New Mexico, U.S., December 2003.

22. Dong, Lei. "IF [Intermediate Frequency] GPS Signal Simulator Development and Verification." Report no. 20184. University of Calgary [Alberta, Canada] Department of Geomatics Engineering. December 2003.

23. Geyer; Frazier.

Further Reading From FSF Publications

FSF Editorial Staff. "RVSM Heightens Need for Precision in Altitude Measurement." *Flight Safety Digest* Volume 23 (November 2004).

FSF Editorial Staff. "Charts Raise Pilot Awareness of Minimum Vectoring Altitudes." *Flight Safety Digest.* Volume 23 (September 2004).

FSF Editorial Staff. "A Signal For Help Is Heard, Help Arrives Too Late." *Flight Safety Digest.* Volume 22 and Volume 23 (September 2003–February 2004).

FSF Editorial Staff. "The Search-and-rescue System Will Find You — If You Help." *Flight Safety Digest.* Volume 22 and Volume 23 (September 2003–February 2004).

FSF Editorial Staff. "Erroneous ILS Indications Pose Risk of Controlled Flight Into Terrain." *Flight Safety Digest.* Volume 21 (July 2002).

Global Aviation Information Network (GAIN) Aviation Operator Safety Practices Working Group. "Operator's Flight Safety Handbook." *Flight Safety Digest* Volume 21 (May–June 2002).

Department of Transport and Regional Development, Bureau of Air Safety Investigation, Australia. "Advanced-technology Aircraft Safety Survey Report." *Flight Safety Digest* Volume 18 (June–August 1999).

Wiener, Earl L.; Chute, Rebecca D.; Moses, John H. "Transition to Glass: Pilot Training for High-technology Transport Aircraft." *Flight Safety Digest.* Volume 18 (June-August 1999).

Sumwalt, Robert L. III "Enhancing Flight-crew Monitoring Skills Can Increase Flight Safety." *Flight Safety Digest* Volume 18 (March 1999).

National Civil Aviation Review Commission. "A Safe Flight Into the Next Millennium." *Flight Safety Digest.* Volume 17 (January 1998).

Human Factors Team, U.S. Federal Aviation Administration. "The Interfaces Between Flightcrews and Modern Flight Deck Systems." *Flight Safety Digest* Volume 15 (September–October 1996).

U.S. Civil Turbine-engine Helicopter Accidents Increased in 2003

Data showed higher accident rates for single-engine helicopters than for multi-engine helicopters.

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The U.S. civil-helicopter accident rate increased in 2003 for single-engine turbine helicopters and for multi-engine turbine helicopters (Table 1, page 14). The fatal-accident rate increased for single-engine turbine helicopters and declined for multi-engine turbine helicopters.

Helicopter Association International, using data from the U.S. Federal Aviation Administration and the U.S. National Transportation Safety Board, compiled data for U.S. civil helicopter safety trends.[1]

At 1.39 fatal accidents per 100,000 flight hours for single-engine turbine helicopters, the 2003 rate was the highest in the 1999–2003 period. The rate of 1.23 fatal accidents per 100,000 flight hours for multi-engine turbine helicopters was the second-lowest in the five-year period.

The data for single-engine turbine helicopters and multi-engine turbine helicopters showed 3.12 and 1.97 fatalities per 100,000 flight hours, respectively. In three years of the five-year period, the fatality rate was higher than 2003 for multi-engine turbine helicopters.

The total number of single-engine turbine helicopter accidents, 83, was an increase from 80 in 2002 but 5.5 percent lower than the 1999–2002 average of 87.8. The total number of multi-engine turbine helicopter accidents, 20, was an increase from 16 in 2002 and 25 percent higher than the 1999–2002 average of 16.

Fatal accidents totaled 17 for single-engine turbine helicopters, compared with 12 in 2002 and 13.3 percent higher than the 1999–2002 average of 15. For multi-engine turbine helicopters, there were five fatal accidents, compared with six in 2002 and 9.1 percent lower than the 1999–2002 average of 5.5.

Phase-of-operation data for 2003 (Table 2, page 15) showed that the greatest number of accidents for all civil helicopters (including reciprocating-engine helicopters) occurred during maneuvering (51 accidents), followed by landing (32 accidents) and cruise (29 accidents).[2] Preliminary causal factors included human factors in 105 accidents, followed in numerical order by engine failure/malfunction (44 accidents) and mechanical failure (26 accidents).

A large majority of civil helicopter accidents (188 of 211, or 89.1 percent) occurred in daylight conditions and in visual meteorological conditions (202 of 211, or 95.7 percent).

The greatest number of accidents involving civil helicopters (Table 3, page 16) occurred during instructional flight (42 accidents, compared with 37 in 2002), followed by personal use (40 accidents, compared with 50 in 2002). There were 15 accidents involving helicopters in emergency medical service in 2003, compared with 11 in 2002. Based on the 1994–2003 averages, the greatest percentage of accidents involved personal use (20.7 percent), followed by instructional flight (15.9 percent) and public use (10.2 percent). ■

Table 1
U. S. Civil Helicopter Accident Trends, 1999–2003

	1999	2000	2001	2002	2003
Civil helicopters — estimated hours flown					
Total helicopter hours flown (in millions)	2.744	2.308	2.141	2.110	2.125
Number of civil helicopter accidents					
Total number of civil helicopter accidents	197	206	182	205	212
Total number of fatal helicopter accidents	31	35	29	26	37
Total number of fatalities	57	63	51	41	67
Total number of serious injuries	44	42	34	51	51
Total number of minor injuries	81	81	71	58	82
Accident rate per 100,000 flying hours					
Accident rate	7.18	8.93	8.50	9.72	9.98
Fatal accident rate	1.13	1.52	1.35	1.23	1.74
Fatal injuries rate	2.08	2.73	2.38	1.94	3.15
Serious injuries rate	1.60	1.82	1.59	2.42	2.40
Minor injuries rate	2.95	3.51	3.32	2.75	3.86
Accidents by helicopter type					
Estimated total flight hours (in millions)					
Single-engine turbine	1.744	1.424	1.203	1.215	1.219
Multi-engine turbine	0.444	0.353	0.355	0.405	0.406
Reciprocating engine	0.556	0.531	0.583	0.490	0.500
Total number of accidents					
Single-engine turbine	92	97	82	80	83
Multi-engine turbine	16	19	13	16	20
Reciprocating engine	89	90	87	109	109
Total number of fatal accidents					
Single-engine turbine	15	19	14	12	17
Multi-engine turbine	7	6	3	6	5
Reciprocating engine	9	10	12	8	15
Total number of fatalities					
Single-engine turbine	29	30	22	19	38
Multi-engine turbine	17	17	5	10	8
Reciprocating engine	11	16	24	12	21
Accident rate per 100,000 hours flown					
Single-engine turbine	5.28	6.81	6.82	6.58	6.81
Multi-engine turbine	3.60	5.38	3.66	3.95	4.93
Reciprocating engine	16.01	16.95	14.92	22.24	21.80
Fatal accident rate per 100,000 hours flown					
Single-engine turbine	0.86	1.33	1.16	0.99	1.39
Multi-engine turbine	1.58	1.70	0.85	1.48	1.23
Reciprocating engine	1.62	1.88	2.06	1.63	3.00
Fatalities rate per 100,000 hours flown					
Single-engine turbine	1.66	2.11	1.83	1.56	3.12
Multi-engine turbine	3.83	4.82	1.41	2.47	1.97
Reciprocating engine	1.98	3.01	4.12	2.45	4.20

Source: Helicopter Association International, based on data from U.S. Federal Aviation Administration and U.S. National Transportation Safety Board

Table 2
US. Civil Helicopter Accidents, 1996–2003, by Condition

	1996	1997	1998	1999	2000	2001	2002	2003
Accident data								
Total accidents	176	163	191	197	206	182	205	211
Fatal accidents	32	27	34	31	35	29	26	37
Fatal injuries	54	43	66	57	63	51	41	67
Serious injuries	34	62	26	44	42	34	51	51
Minor injuries	56	79	55	81	81	71	58	82
No injuries	184	157	197	205	202	223	267	233
Minor or no damage	0	0	1	6	0	6	2	2
Substantial damage	129	111	139	153	154	145	174	166
Aircraft destroyed	46	50	51	38	52	31	29	43
Unknown	1	2	0	0	0	0	0	0
Phase of operation								
Standing	7	3	2	6	6	9	6	6
Taxi	2	0	1	2	0	1	2	3
Takeoff	17	16	16	22	16	21	33	16
Climb	4	7	7	6	7	3	2	5
Cruise	40	26	38	33	32	25	43	29
Approach	4	13	19	8	16	13	17	4
Landing	8	16	17	25	25	22	22	32
Maneuvering	44	34	40	40	49	25	36	51
Hover	28	19	15	20	21	21	7	28
Autorotation	15	18	22	22	26	19	22	19
Other/unknown	7	11	14	13	8	23	15	18
Preliminary causal factors (multiple factors possible)								
Engine failure/malfunction	32	37	38	27	25	37	40	44
Mechanical failure	16	10	16	8	19	18	16	26
Structural failure	12	12	17	10	11	1	5	9
Weather	7	7	6	9	8	4	12	12
Human factors	106	95	111	134	119	113	135	105
Wirestrikes	8	9	13	11	13	10	16	9
Flight conditions								
Day	165	149	173	178	187	168	192	188
Night	11	14	18	19	19	14	13	23
Unknown	0	0	0	1	0	0	0	0
Visual meteorological conditions	168	157	187	188	193	175	201	202
Instrument meteorological conditions	8	6	4	9	13	7	3	9
Unknown	0	0	0	1	0	0	1	0

Source: Helicopter Association International, based on data from U.S. Federal Aviation Administration and U.S. National Transportation Safety Board

Table 3
U.S. Civil Helicopter Accidents, 1994–2003, by Activity, as a Percentage of Total Accidents

Activity	1994	1995	1997	1998	2000	2002	2003	10-year Average
Total accidents	218	161	163	191	206	205	212	191
Personal (FARs Part 91)	43 (19.7%)	29 (18.0%)	36 (22.1%)	45 (23.6%)	41 (19.9%)	50 (24.4%)	40 (19.0%)	39.6 (20.7%)
Instructional (FARs Part 91)	33 (15.1%)	24 (14.9%)	30 (18.4%)	32 (16.8%)	31 (15.0%)	37 (18.0%)	42 (20.0%)	30.3 (15.9%)
Public use (FARs Part 91)	n/r	14 (8.7%)	17 (10.4%)	13 (6.8%)	26 (12.6%)	21 (10.2%)	20 (9.5%)	19.4 (10.2%)
Aerial application (FARs Part 137)	20 (9.2%)	22 (13.7%)	15 (9.2%)	24 (12.6%)	25 (12.1%)	15 (7.3%)	18 (8.5%)	19.0 (9.9%)
External load (FARs Part 133)	11 (5.0%)	11 (6.8%)	15 (9.2%)	13 (6.8%)	11 (5.3%)	8 (3.9%)	16 (7.6%)	12.1 (6.3%)
Air taxi (FARs Part 135) (non-emergency medical/air tour)	15 (6.9%)	11 (6.8%)	9 (5.5%)	5 (2.6%)	8 (3.9%)	14 (6.8%)	17 (8.0%)	11.1 (5.8%)
Business (FARs Part 91)	13 (6.0%)	15 (9.3%)	6 (3.7%)	3 (1.6%)	14 (6.8%)	11 (5.4%)	10 (4.7%)	10.3 (5.4%)
Aerial observation (FARs Part 91)	26 (12.0%)	5 (3.1%)	6 (3.7%)	6 (3.1%)	7 (3.4%)	8 (3.9%)	8 (3.8%)	9.4 (5.4%)
Emergency medical service (FARs Part 91 and Part 135)	5 (2.3%)	2 (1.20%)	3 (1.8%)	6 (3.1%)	12 (5.8%)	11 (5.4%)	15 (7.1%)	7.6 (4.0%)
Sightseeing (FARs Part 91)	5 (2.3%)	4 (2.5%)	6 (3.7%)	6 (3.1%)	4 (1.9%)	2 (1.0%)	3 (1.4%)	3.7 (1.9%)
Commercial air tour (FARs Part 135)	9 (4.1%)	2 (1.2%)	2 (1.2%)	2 (1.0%)	5 (2.4%)	2 (1.0%)	5 (2.4%)	3.7 (1.9%)
Utilities (various FARs)	n/r	n/r	3 (1.8%)	3 (1.6%)	3 (1.5%)	3 (1.5%)	1 (0.5%)	2.8 (1.5%)
Electronic news gathering (FARs Part 91)	n/r	n/r	1 (0.6%)	1 (0.0%)	3 (0.2%)	1 (0.5%)	1 (0.5%)	1.4 (0.7%)
Executive/corporate (FARs Part 91)	0 (0.0%)	0 (0.0%)	2 (1.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.5 (0.3%)

FARs = U.S. Federal Aviation Regulations n/r = Not reported

Note: Approximately 10.6 percent of accidents are classified as "Positioning/ferry," "Other aerial work" or "Maintenance/test," and include accidents in which the industry segment could not be determined.

Source: Helicopter Association International, based on data from U.S. Federal Aviation Administration and U.S. National Transportation Safety Board

Notes

1. The report is available on the Helicopter Association International (HAI) Internet site at <www.rotor.com>.
2. One additional 2003 accident was recorded after the data in Table 2 were tabulated, which accounts for the difference between the 211 accidents in Table 2 and the 212 accidents in Table 1 and Table 3. Wright, Richard M. Jr., director of Safety and Flight Operations, HAI. E-mail communication with Darby, Rick. Alexandria, Virginia, U.S., Nov. 4, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S.

STATS

Reference Book Takes Comprehensive View of Worldwide Civil Aviation

A large-scale overview surveys 'the scope and global structure of international civil aviation, the organizational structure, aims and activities of its main partners, and their products and services.'

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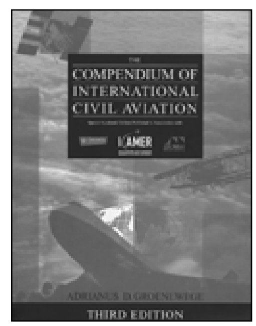
Books

The Compendium of International Civil Aviation. Groenewege, Adrianus D. Third edition. Montreal, Canada: International Aviation Development Corp., 2003. 1,362 pp. Figures, tables, references, glossaries, appendixes, bibliography.

The Compendium of International Civil Aviation (CICA) is an encyclopedic air transport reference book. "The main purpose of the compendium is to serve as a practical and comprehensive source of information on all aspects of international civil aviation activities and developments worldwide," says the author. "It is for use primarily by civil aviation authorities, airline [management] and airport management, and other parties involved in commercial aviation. As a basic reference document, [CICA] is intended to bring about a better understanding of the scope and global structure of international civil aviation, the organizational structure, aims and activities of its main partners, and their products and services provided to the world aviation community."

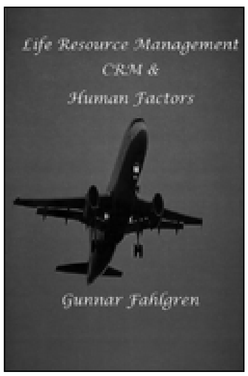
The book discusses international-aviation topics such as the following:



- Milestones, events and developments from 1900 to 2002;
- The structure of international civil aviation, which includes the text of the main International Civil Aviation Conventions and other legal instruments;
- The "three pillars" of civil aviation — the International Civil Aviation Organization (ICAO), the International Air Transport Association (IATA) and the Airports Council International (ACI), with descriptions of their essential publications;
- "World partners" (details of associations, companies and organizations such as Flight Safety Foundation);
- An alphabetical overview of aviation concepts, programs and systems;
- Definitions and descriptions of terms used worldwide;

- Explanations of abbreviations and acronyms;
- Listings of world airline codes, world airport codes and country codes;
- Aircraft classification and nationality marks; and,
- Conversion factors and tables for weights and measures.

Stamp collectors and vintage-aircraft enthusiasts will appreciate the bonus of four pages of full-color reproductions of aviation-themed postage stamps.



Life Resource Management CRM & Human Factors. Fahlgren, Gunnar. United States: Creative Book Publishers, 2004. 231 pp. Figures, references. <www.creativebookpublishers.com>

Capt. Fahlgren, a former flight instructor and former chief pilot of the Scandinavian Airlines System, draws on his own piloting experience as well as his studies of psychology for this exploration and interpretation of human factors and their implications for aviation safety.

"Unfortunately, we often hear that human factors get the blame for this or that accident," says the author. "Maybe I am being a bit provocative when I state that human factors do not cause any accidents. Human failure causes accidents, but not human factors. … The most important thing to learn about human factors is to know which external factors have a negative influence on — or might completely block — our human factors."

The author suggests the following as "human factors destroyers": stress, fatigue, illness, insufficient training, drugs, hunger and thirst, lack of oxygen, and unsuitable mental attitudes, particularly complacency, to which a chapter is devoted.

Four types of complacency are cited:

- Technology complacency. "The advances made in modern technology are forcing us into an ever-increasing position of dependency," says the author. "We gradually get a feeling that technical systems take care of all problems on board. The knowledge and feelings that a technical system very well can fail are pushed further and further into the background";
- Leadership complacency. "A captain, unaware of his behavior, can create an atmosphere where his crewmembers feel tense and uneasy," says the author. "Maybe the captain does not listen, maybe he is irritated, and has negative body language, which most likely will cause a very negative atmosphere in his cockpit … .

  "In this tense atmosphere his first officer will stop supporting him with the benefit of his experience and may even suppress his doubts about the captain's performance. A wrong course of action might not be corrected, and it might even go so far that the first officer is waiting, with pleasure, for the captain to make a mistake";
- Management complacency, which can develop "in an environment with bad communication between an individual and the system in which he is working," says the author. In this situation, employees feel that their employer ignores their ideas and concerns.

  "As nobody asks for a pilot's knowledge and feelings regarding flight safety, or other important issues, he might gradually be transformed into a person who does not give information anymore," says the author. "He might even stop asking for information from his own colleagues. Finally, he even stops asking his own memory for knowledge"; and,
- Self-induced complacency — a decline in motivation, discipline or concentration. This form of unconscious sabotage can happen if a pilot becomes resentful, says the author, such as when a former captain finds himself in the right seat as the result of an airline merger, or when a first officer believes he is overdue to be promoted to captain.

AIM/FAR 2005: Aeronautical Information Manual/Federal Aviation Regulations. Spence, Charles F. (ed.). New York, New York, U.S.: McGraw-Hill, 2005. 984 pp. Figures, tables, references, glossaries, appendixes, index.

"Reading this publication certainly doesn't have the appeal of a good mystery or biography, but it can be exceptionally important," says the editor.

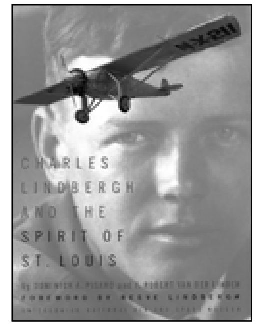
The *Aeronautical Information Manual* (*AIM*) and Federal Aviation Regulations (FARs) are published by the U.S. Federal Aviation Administration (FAA) to inform pilots and others in the aviation community of basic flight information, regulatory requirements and basic air traffic control (ATC) procedures. This book combines the complete text of the *AIM* with what is judged to be the most significant information from the FARs for pilots. Additionally, there are editorial explanations and cross-references to other FAA operational publications.

Chapters of the *AIM* address navigation aids; lighting and visual aids; airspace; air traffic control; air traffic procedures; emergency procedures; safety of flight; medical facts; charts and publications; helicopter operations; and a pilot/controller glossary.

The second half of the book contains pertinent sections of U.S. Transportation Security Administration (TSA) requirements for general aviation and FARs concerning such subjects as definitions and abbreviations; maintenance; certification of pilots, instructors and air traffic controllers; medical standards and certification; use of airspace; general operating and flight rules; standard instrument approach procedures; and others.

Two major regulatory changes are included in this edition: The Sport Pilot and Light-sport Aircraft rule and the regulations pertaining to fractional ownership. "Changes for the sport-pilot regulations are found in [FARs] Parts 1, 43, 61, 65 and 91," says the editor. "The fractional-ownership regulation has a large new section in Subpart K of Part 91, and the effects of this change are sprinkled throughout other parts of the FARs."

The book and its companion Internet site are intended to help pilots stay current in important safety knowledge, FAA civil aviation rules and pertinent sections of the FARs. Text in the book that has changed since the previous edition is highlighted, and the changes are explained. Because changes to the documents may occur at any time, the editor tracks FAA changes and rulemaking and posts significant changes on the Internet site <books.mcgraw-hill.com/engineering/update-zone.html>.



Charles Lindbergh and the Spirit of St. Louis. Pisano, Dominick A.; Van der Linden, F. Robert. Foreword by Lindbergh, Reeve. Washington, D.C., U.S.: Smithsonian National Air and Space Museum, in association with Harry N. Abrams, 2002. 144 pp. Illustrations, glossary, bibliography, index.

On May 21, 1927, thirty-three hours after taking off from Westbury, New York, U.S., Charles Lindbergh had almost achieved his goal of completing the first solo, nonstop transatlantic flight. In the cockpit of the *Spirit of St. Louis*, over Paris, France, the former stunt pilot and airmail pilot did not expect anyone to greet him on landing, and he was concerned that he was arriving without having obtained a visa. Moreover, although he had found Paris, he was not sure where to find Le Bourget Airport. No one he had asked in the United States could offer a more precise location than that it was northeast of the city.

Even when he observed a field illuminated by spotlights, Lindbergh could not determine if it was the airport, and continued flying for a few minutes. Seeing nothing else, he turned back. Spiraling the airplane down, he saw the airport and the windsock. He lined up the *Spirit of St. Louis* over the runway and brought the airplane down into history.

The authors of this book, curators of the National Air and Space Museum of the Smithsonian Institution, recount the history of the flight, but stress its importance as more than an adventure story. The book places the event in the context of aviation's development and describes in detail the design of Lindbergh's aircraft, as well as his careful preparation for the flight.

The authors discuss the significance of the overwhelming celebrity, reaching cult status, that surrounded Lindbergh following his feat. (The front page of *The New York Times*, shown in one of the book's 82 photographic illustrations, was entirely given over to stories about "Lindy.")

"How does one begin to account for the Lindbergh phenomenon?" the authors ask. "Certainly, the fact that he dared to test himself alone against the formidable ocean made him a hero in the eyes of many. … A more emblematic explanation for the Lindbergh phenomenon is that to a nation transformed by World War I and the turbulent era of the 1920s, Lindbergh and his flight represented a way to reconcile traditional American values with the increasingly complex and confusing new technological age."

In the immediate aftermath of the flight, many preferred to think of Lindbergh as a daredevil rather than as a skilled pilot and navigator. Yet, the authors say, it was a key part of the process in which aviation evolved from a fringe phenomenon into an economically viable endeavor that began to assume a more central role in contemporary life.

"After Lindbergh's famous flight, and this is where his importance has been neglected, popular enthusiasm for flying took on new dimensions," the authors say. "Pulp fiction, advertising, films, the comics, industrial and automotive design, and vernacular architecture were just a few of the areas that borrowed heavily from aviation in the 1930s. Moreover, Lindbergh's flight reinforced the image of the airplane as a machine of progress, savior of American ideals and a symbol of a future transformed by technology."

Charles Lindbergh and the Spirit of St. Louis also offers glimpses of the man, both before and after his most famous achievement, as distinct from the "celebrity hero" that the public made of him. In his early days as a barnstormer, the authors say, "the feats Lindbergh performed were not only difficult physically but also emotionally because he had to overcome the fear generated by recurring nightmares as a child of falling from great heights."

Metaphorically, falling from a great height was what happened to Lindbergh in the 1930s. "Despite the adulation of the press and public, Lindbergh soon began to tire of what he thought was the undue attention paid to him and the invasion of his privacy, and he began to react against the press and the public," the authors say. "Lindbergh's patience with the press and public reached breaking point when his son, Charles Jr., was kidnapped from the family home in Hopewell, New Jersey, in March 1932.

"Like the transatlantic flight, the kidnapping elicited an exaggerated reaction from the press. Reporters swarmed en masse onto the Lindbergh estate looking for stories and interviews, not only making themselves unpleasant but jeopardizing both the investigation and the return of the baby [which was found dead more than two months after the kidnapping]."

Lindbergh and his wife, Anne Morrow Lindbergh, moved to England. In the late 1930s, he alienated many Americans with his outspoken support of isolationism and his several visits to Germany, during one of which he was decorated by Hermann Goering, commander of the *Luftwaffe*. Nevertheless, he volunteered to serve in the Army Air Corps when the U.S. entered World War II (although opposition from the administration of President Franklin D. Roosevelt kept him out of the military).

As a technical representative for United Aircraft during the war, he went to the South Pacific to test fighter aircraft such as the Vought F4U Corsair and the Lockheed P-38. "At war's end, and despite official disapproval, he had flown 50 unauthorized combat missions and was credited with shooting down a Japanese fighter," the authors say. As he adopted mainstream anti-Communist views in the postwar years and became involved in nature conservation later in his life, Lindbergh's reputation was largely restored.

"But there had been a profound change in his priorities," the authors say. "Although he was still active in aviation, Lindbergh had come to question it and to reflect on its ultimate value. His interest in things scientific and technological gradually gave way to a concern for the fragile planet and the spiritual development of mankind in a world of materialistic values. …

"Despite his immense influence on aviation, it is not certain that Lindbergh's substantial contributions — his technical expertise and his lifelong efforts toward placing American aviation on a sound footing both commercially and technologically — were ever fully comprehended by the American people. … In their search for a popular hero, the vast majority of Americans were concerned more with Lindbergh as a celebrity or villain than with the pattern of his life."

Reports

Final Report on the Follow-on Activities to the HOMP Trial. U.K. Civil Aviation Authority (CAA) Safety Regulation Group (SRG). Civil Aviation Paper (CAP) 2004/12. October 2004. 94 pp. Figures, tables, appendixes, glossary, references. Available on the Internet at <http://www.caa.co.uk> or from Documedia.*

The report says that "the Helicopter Operations Monitoring Program (HOMP) is a helicopter version of fixed-wing flight data monitoring (FDM) programs." CAP 739, *Flight Data Monitoring, a Guide to Good Practice*, 2003, defines FDM as "the systematic, proactive and nonpunitive use of digital flight data from routine operations to improve aviation safety."

Since the 1970s, the CAA SRG has helped develop and support FDM systems and has used FDM information to support airworthiness and operational safety tasks. In the spirit of cooperative development, says the report, many operators have demonstrated the safety benefits of FDM, so that the International Civil Aviation Organization (ICAO) has recommended the use of FDM "for all air transport operations in aircraft of over 20 tonnes [44,000 pounds] maximum weight effective Jan. 1, 2005. The U.K., in continuing its policy of applying ICAO standards, will make this a requirement under U.K. law, and other European regulators are also expected to comply."

The first HOMP application of FDM occurred in 1999 when the CAA conducted a trial of an FDM program for North Sea helicopters. Five Aerospatiale 332L Super Puma helicopters were equipped with recorders to extract and download flight data. The trial consisted of an eight-month development phase, followed by a two-year operational phase that was completed in late 2001.

The report says that the HOMP trial achieved excellent results, demonstrating that HOMP could bring about improvements in flying practice and flying training, improvements in operating procedures and improvements in an operational environment. This success resulted in a commitment by members of the United Kingdom Offshore Operators Association and the CAA to fund activities for implementation of HOMP on all flight data recorder (FDR)-equipped U.K. public transport helicopters operating over the U.K. continental shelf.

In the HOMP trial, one operator, Bristow Helicopters, implemented HOMP on five of its North Sea fleet of Super Puma helicopters.

In follow-on activities, to help facilitate wider implementation of HOMP, the CAA funded a program to transfer HOMP to a second U.K. operator, CHC Scotia, on two Super Pumas, and to develop the HOMP for a second helicopter type, the Sikorsky S-76A (also operated by Bristow Helicopters).

The CAA says, "The results of the follow-on activities provide further evidence of the safety benefits of HOMP. Both [Bristow] and Scotia identified significant safety issues as a result of their HOMP programs and were able to take corrective measures to address them. … The results have also served to broaden the general HOMP knowledge base which, it is hoped, will assist and encourage the wider implementation of HOMP.

"In March 2004, the ICAO Helicopter Tiltrotor Study Group unanimously agreed to propose to add HOMP to ICAO Annex 6, Part III, as a recommended practice for flight data recorder-equipped helicopters."

This final report describes details of activities in the follow-on trial, operational experiences, flight data events, flight data measurements, and application of data-mining techniques to event data. The recommendations include the following:

- Helicopter operators should implement HOMP on all FDR-equipped commercial air transport helicopters;
- Operators should ensure that HOMP is properly integrated into a company's safety management system;
- Standardize the core HOMP events used by different operators to aid in the sharing of information and knowledge;

- Establish a standardized methodology for event severity and provide guidelines on factors to be considered in severity allocation;

- Develop data-mining techniques for efficient analysis of HOMP events; and,

- Develop measurement databases to identify hidden event trends and anomalies in measurement data prior to the triggering of any events.

The report also recommends investigation of additional possible HOMP applications, such as monitoring global positioning system (GPS) performance.

Regulatory Materials

U.S. Airworthiness Certificates and Authorizations for Operation of Domestic and Foreign Aircraft. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 20-65A. July 8, 2004. Table, references. 6 pp. Available from FAA via the Internet at <http://www.airweb.faa.gov/Regulatory_and_Guidance_Library> or from USDOT.**

This AC offers general information about the issuance of the following certificates and authorizations:

- Standard airworthiness certificates (FAA Form 8100-2) for U.S.-registered aircraft;

- Special airworthiness certificates (FAA Form 8130-7) for U.S.-registered aircraft; and,

- Special flight authorizations (SFAs) for operating, within the United States, non-U.S. aircraft that do not have standard airworthiness certificates issued by the country of registry.

"This AC describes an acceptable way, but not the only way, to comply with [the relevant U.S. aviation regulations]," says the AC. "However, if you use the AC, you must follow it in all important aspects."

The AC outlines procedural steps for obtaining certification and for obtaining authorization, identifies documentation and forms to be filed, lists information to be included in applications, and notes that FAA may require prescriptive limitations or operational limitations if necessary for safety.

For special flight authorization, the AC says that "a civil aircraft registered in a country that is a member of the International Civil Aviation Organization (ICAO) needs only a special flight authorization issued by the FAA. A civil aircraft registered in a country that is not a member of [ICAO] always requires an authorization from the United States Department of Transportation (USDOT) and a special flight authorization issued by the FAA to operate in the United States."

This AC affects production approval holders (PAHs) and individual owners of civil aircraft who need to obtain airworthiness certificates or SFAs from FAA. It incorporates current requirements and includes references to related documents, including other ACs and parts of the U.S. Federal Aviation Regulations (FARs), that FAA recommends an applicant study before requesting an airworthiness certificate or SFA.

It is suggested that PAHs and owners review FAA Order 8130.2, *Airworthiness Certification of Aircraft and Related Products*, to better understand the process.

[This AC cancels AC 20-65A, *U.S. Airworthiness Certificates and Authorizations for Operation of Domestic and Foreign Aircraft*, dated Aug. 11, 1969.] ■

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A320's Tail Scrapes Runway During Bounced Landing

The incident occurred as the first officer, who was undergoing a 'protracted period' of line training, flew the airplane without the autopilot, autothrottles and flight directors.

— 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

Incident Prompts Recommendations for Review of Training

Airbus A320. Minor damage. No injuries.

Daytime visual meteorological conditions prevailed for the approach to an airport in England following a flight from Greece. The airplane was being flown by the first officer, who had accumulated 327 flight hours during line training and had been scheduled to fly for four consecutive days with the same line-training captain. At Flight Level (FL) 250 (approximately 25,000 feet), the flight crew disengaged the autopilot, autothrottles and flight directors.

The crew had requested a straight-in landing on Runway 27, although the wind was from the southeast and Runway 9 was in use. Air traffic control (ATC) initially agreed, and the crew positioned the airplane and briefed for an approach and landing on Runway 27. When the airplane reached FL 110, ATC said that because another aircraft was being positioned for landing on Runway 9, the crew of the incident airplane also would receive vectors for a landing on Runway 9. The captain reprogrammed the flight management system for landing, and the crew followed ATC vectors until the airplane was established on the instrument landing system (ILS) approach.

"Although the [first officer] followed the ILS localizer indications, the [captain] was aware that the aircraft had in fact become slightly displaced to the right of the runway centerline," the accident report said. About 300 feet above touchdown zone elevation, the captain told the first officer to look up and to correct the airplane's track back to the centerline. About 100 feet above the runway threshold, the crew estimated that the airplane was aligned with the centerline and that the wings were level.

"The [first officer] commenced the flare at 50 feet [above ground level (AGL)] and retarded the thrust levers at 30 feet AGL, but it became apparent that the aircraft was descending more rapidly than normal," the report said. "He maintained back pressure on his side stick, but in an attempt to cushion the landing, the [captain] also applied back pressure to his side stick. When making his control input, the [captain] did not press his side-stick priority-takeover pushbutton."

The airplane touched down firmly on the main wheels, bounced and touched down again. ATC told the crew that the airplane's tail had scraped the runway. There were no abnormal indications on the flight deck, and the airplane was taxied to the gate (stand).

The report said that the accident resulted from "an accumulation of factors" beginning with the maneuver to realign the airplane with the centerline between 300 feet AGL and 100 feet AGL and culminating with the 13.4 degrees of nose-up pitch on the second touchdown, which resulted in the tail strike.

The airplane and pilots were operating from the airport in England under a six-month wet-lease agreement. They usually were based in Canada, where regulations required a minimum of 25 flight hours of line training before the line check. The operator typically extended that time to 50 flight hours, and the first officer, who had a total of 840 flight hours, was undergoing "a protracted period of line training" because of his relative inexperience.

The captain recently had been designated a line-training captain but had received only a verbal briefing on the requirements of the position.

As a result of the investigation, the U.K. Air Accidents Investigation Branch recommended that the operator review policies and procedures for training new pilots and new training captains, and that Airbus emphasize to airlines "the need for pilots to press the side-stick priority[-takeover pushbutton] when intervening to correct an erroneous control input by the handling pilot" and introduce an aural warning to its fly-by-wire aircraft to alert pilots to excessive pitch angle or excessive pitch rate during landing. After the incident, the operator implemented several safety actions, including issuing information on use of autothrust, speed monitoring and the side-stick priority-takeover pushbutton; modifying training to include more information on recovery from bounced landings, flight-control takeover, low-energy awareness and monitoring pitch and airspeed during approach and landing; increasing training and oversight in the training-pilot program; and implementing a new pilot-recruitment standard."

Engine Separates From Airplane During Climb

Boeing 747. Substantial damage. No injuries.

Nighttime visual meteorological conditions prevailed for the cargo flight's departure from an airport in the United States. As the crew flew the airplane through 16,000 feet, the no. 1 engine separated from the airplane and fell into a lake in an area where the water was about 240 feet (73 meters) deep.

The crew diverted to an en route airport. A post-landing inspection revealed that the engine had separated at the forward engine-mount bulkhead and the aft engine mount. A preliminary report said that the forward engine-mount bulkhead was deformed and the aft engine mount was intact, with part of the engine turbine exhaust case still attached. The pylon was still attached to the wing, and pylon-alignment marks were aligned.

The crew had reported no abnormal conditions before the engine separation. Investigation of the incident was continuing.

Flight Crew Sickened By Fumes

Boeing 737. No damage. Minor injuries.

During passenger boarding at an airport in Australia, the crew detected a "pungent burning smell" while they conducted preflight checks, a report said. They told passengers to exit the airplane.

The first officer felt faint, and the captain was dizzy and weak, with shaking hands, watering eyes and tingling fingers. The cabin supervisor administered oxygen to both flight crewmembers, and the captain was taken to a hospital for observation.

An examination of the airplane revealed a burned diode on a circuit board behind the first officer's seat; the damage resulted from excessive heating under electrical load. The diode was a plastic-cased component that differed from the original hermetically sealed, metal-cased glass diode. The report said that the flight crew was "physically affected as a result of exposure to the fumes produced from the combustion of the failed diode."

AIR TAXI/COMMUTER

Airplane Slides Off Wet Runway After Landing Roll

De Havilland DHC-8 Dash 8. Minor damage. No injuries.

As the crew flew the airplane on final approach to Runway 15 at an airport in England after a flight from Scotland, they heard a controller in the air traffic control tower tell the crew of an aircraft on the ground to "line up" on the runway "after the landing Dash 8." They also heard the crew of another aircraft report that they were eight nautical miles (15 kilometers) from touchdown.

As the Dash 8 touched down and continued toward the turnoff at the end of the runway, the controller told the crew of the airplane lining up on the runway to expect takeoff clearance "in about 10 seconds" and told the crew of the aircraft on approach to expect a late landing clearance.

The captain of the Dash 8 said that, as the airplane neared the end of the runway at a "normal, if expeditious, speed," the crew began a left turn.

"As the nose of the aircraft turned through approximately 30 degrees off the runway heading, the nosewheel began to slide, and, with insufficient runway remaining or corrective action, the aircraft ran off the paved runway/taxiway intersection and sank up to its axles in the soft ground beyond," the report said.

The crew of the approaching airplane was told to go around, and the runway was closed.

Weather at the time included wind from 180 degrees at 14 knots, gusting to 22 knots; visibility of 9,000 meters (5.6 statute miles) in light rain; and an overcast at 300 feet. The runway was wet, and a friction test conducted one hour after the incident indicated that braking action was good.

The runway is 2,605 meters (8,547 feet) long, with a landing distance of 2,279 meters (7,477 feet). Most of the surface is grooved asphalt; the last 150 meters (492 feet) are concrete. An intersecting runway sometimes is used as a taxiway to the terminal; the only other taxiway that leads directly to the terminal from Runway 15 is at the end of, and perpendicular to, the runway.

"Aircraft landing on Runway 15 unable to turn off at the [intersecting runway] must continue for approximately 1,000 meters [3,281 feet] to this final exit in order to vacate the runway, often expeditiously to avoid delaying subsequent runway movements," the report said.

An evaluation of the runway's surface friction conducted before the incident (and after a previous incident in which a Boeing 767 ran off the end of the runway) found that friction values over some of the runway's painted markings — including an area near the turnoff at the end of the runway — were such that the area might be slippery when wet. Those areas had been painted with "friction paint." Another area on the concrete section of the runway, not associated with painted markings, also was found to be below the minimum friction level — the level at which it might be slippery when wet.

Information retrieved from the airplane's flight data recorder showed that the airspeed at the beginning of the turnoff was about 40 knots and as the turn continued through 30 degrees left of runway heading, the airspeed was 34 knots.

After the incident, the operator issued a notice to pilots, telling them to reduce speed to normal taxi speed "well before attempting any sharp turns to exit a runway"; to be "extra cautious" on concrete — especially wet concrete; not to feel pressured to expedite runway clearance; and to avoid excessive steering angles except at very low speeds. In addition, the airport planned to construct another runway turnoff about 420 meters (1,378 feet) before the end of the runway.

Aircraft Strikes Frozen Lake During Descending Departure Turn

Beech 99. Substantial damage. No injuries.

Nighttime visual meteorological conditions prevailed for the series of scheduled flights to several small communities in Canada. During the flights, the first officer became ill, and a relief pilot was flown in as a replacement.

Because of seniority, the relief pilot became the new captain, and the original captain became the new first officer. Because the original captain had flown the airplane from the left seat and the cockpit had been configured to accommodate him, he remained in the left seat, and the new captain took the right seat. The company's operations manual said that a left-seat-qualified pilot could operate the aircraft from the right seat if the pilot had received annual right-seat training. The new captain had not received such training while a captain with the company.

The original captain (now the first officer but still flying the airplane from the left seat) flew the airplane on the first leg after the crew change. After landing, the crew worked in a brightly lighted area of the ramp as they prepared for the next leg, which was flown by the new captain from the right seat. The captain, who had dimmed the lighting on the right side of the cockpit for his first leg of the flight, did not readjust the lighting for the next leg.

After departure, the captain intended to conduct a climbing right turn with a bank angle of 20 degrees to 25 degrees.

The accident report said, "During the turn, the [captain] had difficulty seeing the artificial horizon [because of low illumination] and concentrated on the aircraft's bank angle. The first officer called that the aircraft was in a 2,000-feet-per-minute descent and took control. The aircraft struck the frozen surface of [a] lake, bounced and became airborne again. The first officer retained control, and the captain attempted to feather the damaged right propeller. The first officer, believing that both propellers had sustained damage, force-landed the aircraft on the lake surface."

The report said that findings as to causes and contributing factors were that "the captain chose to fly the aircraft from the right seat during a night departure when not current to operate the aircraft from the right seat" and that "the captain did not set the instrument lighting correctly for the night takeoff and was unable to use the artificial horizon effectively, resulting in the loss of situational awareness after takeoff and the subsequent loss of control of the aircraft."

Nosewheel Separates From Airplane During Landing

Cessna 210N. Substantial damage. No injuries.

During the landing roll at an airport in Australia, the nosewheel separated from the airplane. The airplane, which had been flown on a charter passenger flight, flipped over, and the pilot and passengers exited the airplane. (The report did not say how many passengers were in the airplane.)

The operator's examination of the airplane revealed that the self-locking nut and bolt for the nose-landing-gear wheel axle had separated from the landing gear, either before or during takeoff. (The bolt and a washer were found on the runway at the departure airport.) During landing, the wheel became loose and then separated.

The report said that, as a result of the occurrence, the operator began inspecting its aircraft "to ensure that only new through-bolt retaining nuts are installed."

Difficult Engine Start Preceded Takeoff Accident

Beech 60 Duke. Substantial damage. Four fatalities.

Daytime instrument meteorological conditions prevailed and an instrument flight rules flight plan was filed for the business flight in the United States. Witnesses said that the pilot had difficulty starting the airplane's right engine and that after the engine started, the pilot immediately taxied the airplane onto the runway and began a takeoff roll.

The airplane was about 3,000 feet (915 meters) down the 8,000-foot (2,440-meter) runway at 100 feet to 150 feet with the landing gear retracted when witnesses heard a loud bang. They said that the pilot did not try to land on the remaining runway; instead, the airplane appeared to gain "a little" altitude before passing the departure end of the runway.

"At that point, the airplane began a right descending turn and was in a 60[-degree] to 80-degree right bank, nose-low attitude, when they lost sight of it," a preliminary accident report said. "A few minutes later, they heard the fire department responding."

The wreckage was found about 0.75 nautical mile (1.39 meters) from the departure end of the runway. The investigation was continuing.

Airplane Strikes Coyote During Takeoff Roll

Cessna Citation V Ultra 560. Minor damage. No injuries.

During takeoff from an airport in Canada, just prior to reaching V_1 (takeoff decision speed) the airplane struck a coyote on the runway. The crew rejected the takeoff and returned to the gate area.

The runway was closed for about 10 minutes for removal of the coyote's remains.

OTHER GENERAL AVIATION

Airplane Strikes Power Line, Ground on Final Approach

Piper PA-23-250 Aztec. Substantial damage. Three minor injuries.

Instrument meteorological conditions prevailed and a visual flight rules flight plan had been filed for the evening flight in the Bahamas. The pilot said that the airplane was about 10 nautical miles (19 kilometers) from the destination airport when the right engine surged.

The fuel selectors had been positioned to their respective outboard fuel tanks, but after the surge began, the pilot cross-fed fuel from the left fuel tank to the right engine. A preliminary report said that power was restored briefly, and the flight continued toward the destination airport.

During final approach, the airplane yawed right. The pilot corrected the yaw with left-rudder trim and applied full power to the left engine. As the descent continued, the airplane struck a power line and the ground.

A preliminary inspection revealed that both outboard fuel tanks were empty and both inboard fuel tanks were full.

Flawed Fuel System Leads to Forced Landing

Cessna 188B. Minor damage. No injuries.

Visual meteorological conditions prevailed for the first leg of the ferry flight from Canada to Uganda. About 90 minutes after departure, as the pilot tried to transfer fuel from a modified fuel tank to the wing fuel tanks, the engine stopped producing power.

The pilot conducted a forced landing on a snow-covered bog in Canada; after the landing, the airplane nosed over. The pilot of an aircraft being flown overhead heard the pilot declare mayday, a distress condition, and radioed authorities, who arranged for a helicopter crew to rescue the pilot.

An investigation revealed that this was the second attempt to ferry the airplane from Canada to Uganda and that the first attempt, more than 10 months earlier, had ended after a different pilot experienced a fuel-transfer problem. The first pilot had returned the airplane to the departure airport, where maintenance personnel performed a number of tasks but did no troubleshooting of the fuel-transfer problem because the operator believed that the problem had resulted from improper operation of the fuel system.

The accident report said that the aircraft fuel system was "heavily contaminated with water and solid particle contaminants" and that the water "probably led to internal corrosion, which resulted in the fuel screens becoming severely contaminated with solid particles."

The report said the contamination and the formation of ice after exposure to cold temperatures at altitude blocked fuel flow to the engine, causing the engine to stop.

"An adequate examination of the fuel system after the initial ferry flight attempt would probably have revealed discrepancies (such as an improperly operating fuel system or fuel contamination) that would have been corrected before the second ferry flight attempt," the report said.

ROTORCRAFT

Wake Turbulence Leads to Landing Accident

McDonnell Douglas Hughes 369E. Destroyed. No injuries.

The helicopter was being flown at 1,500 feet to a landing site in England for a demonstration to a prospective customer. The pilot radioed air traffic control and received clearance through a control zone and an advisory that a large airplane was crossing in front of the helicopter in preparation for landing.

"About a minute later, the pilot described feeling a 'severe vertical bump' causing a descent, followed by an ascent, and at the same time, he heard a mechanical noise," the accident report said. "His immediate thought was that the rear door had opened and something had flown up into the main rotor. However, he … could see that the door was still closed. The helicopter was now suffering significant vibration, and so he lowered the collective and entered autorotation."

The pilot landed the helicopter in a field, where the helicopter flipped over and rolled onto its side.

The report said that 90 seconds before the "bump," an Airbus A319 was flown 300 feet above the position where the turbulence occurred.

The "bump" possibly was "the effect of turbulence caused by a wake vortex," the report said. "The known characteristics of wake vortices are that, unless disturbed, they will persist for several minutes and drift downwards at about 100 [feet per minute] to 200 feet per minute. Wind conditions were light and … it is in just such circumstances that a wake vortex encounter seems likely."

Woman Knocked to Ground by Turbulence From Landing Helicopter

Eurocopter BK 117B-2. No damage. One injury.

Daytime visual meteorological conditions prevailed as the pilot conducted an approach to a hospital heliport in Sweden. The approach and landing required a relatively steep glide to the touchdown area, and during the landing, the helicopter generated "such powerful turbulence … that a woman walking outside the heliport area was knocked over and sustained a fractured hip," the accident report said.

As a result of the investigation, the Swedish Accident Investigation Board recommended that the Swedish Civil Aviation Administration publish information about the problem and "supplement existing regulations for the layout and management of heliports in such ways that the safety of persons and materiel in their proximity is taken into account."

Helicopter Sinks After Emergency Landing in Gulf of Mexico

Bell 206B JetRanger. Substantial damage. One serious injury, one minor injury.

Daytime visual meteorological conditions prevailed for the air taxi flight between two offshore platforms in the Gulf of Mexico. When the helicopter was at 500 feet after a takeoff from one platform, as the pilot switched to a radio frequency for the destination platform, he heard a loud bang, and the engine stopped producing power.

The pilot began an autorotation, deployed the helicopter's emergency floats and — at 50 feet to 60 feet — "started to flare and selected a wave to land on," a preliminary report said. "The helicopter landed hard on the water and remained upright for approximately 20 minutes before it rolled over inverted and partially submerged. The helicopter remained floating inverted near the surface."

The pilot and two passengers evacuated immediately after the helicopter landed; they did not deploy the life raft. Thirty minutes later, another helicopter arrived and dropped a life raft, in which the pilot and passengers waited for further assistance.

The pilot's examination of the helicopter revealed that the tail boom had separated from the fuselage. The helicopter sank during recovery efforts.■

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