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# Charts Raise Pilot Awareness of Minimum Vectoring Altitudes

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# Charts Raise Pilot Awareness of Minimum Vectoring Altitudes

**At least 158 paper charts published by 34 civil aviation authorities currently provide advisory information about minimum vectoring altitudes to pilots. Newly released data for 374 U.S. MVA charts should encourage development of electronic versions that will help to prevent controlled flight into terrain.**

— FSF EDITORIAL STAFF

Although the use of minimum vectoring altitudes (MVAs) by air traffic control (ATC) facilities has been familiar to pilots for decades, civil aviation authorities vary as to whether they publish this information to enable pilots to anticipate assignment of altitudes below those depicted on instrument flight rules (IFR) navigation charts. Various terms and definitions are used for these predefined altitudes. Charts that depict these altitudes also have been offered as a method for pilots to cross-check assigned altitudes during radar vectoring under IFR in controlled airspace.

Radar vectoring is common during IFR operations in terminal areas within the vicinity of one or more major airports, and increases as more aircraft are equipped to conduct area-navigation (RNAV) operations off the routes published on IFR charts. During normal flight operations, pilots may be told by the radar controller — or may not be told — that the MVA has been offered to them during approach or departure.[1]

During the past 35 years, civil aviation authorities increasingly have published paper charts in their aeronautical information publications (AIPs)[2] so that controllers and pilots have the same information about MVAs. Some contain procedures to be used for loss of ATC–pilot communication during radar vectoring.

Paper charts depicting MVAs are available to pilots from Belgium; Bosnia and Herzegovina; Botswana; Chile; Colombia; Costa Rica; Czech Republic; Ecuador; Egypt; France; Germany; Greece; India; Indonesia; Iran; Israel; Italy; Jordan; Malaysia; Mexico; Oman; Panama; Philippines; Poland; Portugal; Russia; Slovenia; Spain; Taiwan, China; Tunisia; Turkey; Ukraine; United Kingdom; and Uruguay, according to August 2004 information compiled in a Jeppesen database (Appendix A, page 23). The three countries with the largest number of such charts in this database were France (29 charts), Mexico (nine charts) and the United Kingdom (41 charts).

Since the 1990s, aviation safety specialists, including the Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force, have said that the most important reason for shared awareness of MVAs is to help prevent controlled flight into terrain (CFIT).

CFIT occurs when an airworthy aircraft under the control of the flight crew is flown unintentionally into terrain, obstacles or water, usually with no prior awareness by the crew. This type of accident can occur during most phases of flight, but CFIT is more common during the approach-and-landing phase, which begins when an airworthy aircraft under the control of the flight crew descends below 5,000 feet above ground level (AGL) with the intention to conduct an approach and ends when the landing is complete or the flight crew flies the aircraft above 5,000 feet AGL en route to another airport.

**"The one missing action is for ATC to make this information available to pilots who want or need it."**

Absence of vertical situation awareness — i.e., when pilots do not know the relationship of the airplane altitude to the surrounding terrain, obstacles and intended flight path — has been identified as a significant causal factor during analysis of global CFIT accidents. In 1997, one working group of the FSF ALAR Task Force said, "With the implementation of the global positioning system (GPS) and flight management system (FMS), it is now possible to display MVA information in an electronic form on the flight deck. The one missing action is for ATC to make this information available to pilots who want or need it. The [working group] strongly recommends that MVA information be made available for use."[3]

The working group said that its conclusion and recommendation were based on the following reasons: "Currently there is a hazardous disconnect between the vectoring charts used by the air traffic controller and those available in the cockpit. The pilot has minimum-sector-altitude (MSA) charts that provide the lowest usable altitude in a sector surrounding an airport. These charts are centered around radar-antenna sites, which in most cases are different from the center point of the MSA charts. As the MSA and MVA charts are based on different criteria, a pilot can become confused when vectored at an altitude that is below the MSA charted altitude. The pilot is not sure whether [he/she] is being radar vectored at an approved MVA altitude or whether a mistake has been made concerning the MSA. This is especially critical in high-density traffic areas where radio congestion may preclude further and immediate clarification with ATC. This is a classic 'latent situation' or 'enabling factor' in the potential error chain."

The risk of CFIT during ATC radar vectoring is minor but not negligible, said Don Bateman, a member of the FSF ALAR Task Force and chief engineer, Flight Safety Avionics, Honeywell International. His worldwide CFIT-accident data for transport category aircraft and reports of terrain warnings help to shed light on the value of MVA charts to pilots.[4]

"The probability of an incorrect altitude assignment in a radar vector, an incorrect aircraft position or ATC radar-vectoring the wrong airplane seems very low, but these errors continue to happen — close calls occur every year," he said. "I would be very surprised to find that an MVA chart was wrong, however." (See "CHIRP, ASRS Reports Suggest Value of MVA Awareness," page 5.)

In some reported incidents, pilots have said that they received questionable radar vectors and that they avoided terrain either on their own or by receiving a terrain warning.

"In one example, an MVA chart would have been very helpful to a captain who refused a radar vector in Central America after realizing that the controller apparently had reversed aircraft call signs and was vectoring the wrong airplane," Bateman said. "This crew had been monitoring their enhanced ground-proximity warning system [EGPWS] display, and one pilot said, 'That's not right — he's got us going right at that terrain' — then the captain refused the vector and corrected the error." (Terrain awareness and warning system [TAWS] is the term used by the European Joint Aviation Authorities and FAA to describe equipment meeting ICAO standards and recommendations for GPWS equipment that provides predictive terrain-hazard warnings; EGPWS and ground collision avoidance system are other terms used to describe TAWS equipment.)

Use of MVA charts on the flight deck should be seen as another dimension of improving safety, he said.

"Current paper MVA charts can add a layer of safety in the cockpit by enabling a pilot to know what to expect in a given terminal area, which is preferable to the pilot having to blindly follow the controller's radar vector," he said. "If questions come up about radar vectors, these MVA charts certainly can be related to aircraft position with VOR DME [very high frequency omnidirectional range and distance-measuring equipment], for example. It can be difficult for pilots to relate the aircraft position to a paper MVA chart, however. Electronic MVA charts especially would be beneficial whenever the pilot is not too sure if the altitude assignment is OK."

Air carriers have considered methods of improving terrain/obstacle awareness for pilots during radar vectoring for decades, said James Terpstra, another member of the FSF ALAR Task Force, who retired in 2004 as senior vice president, flight information technology and aviation affairs, Jeppesen.[5]

"In the mid-1970s, Jeppesen Sanderson researched terrain depiction on IFR charts because a U.S. airline wanted us to put terrain on their charts for terrain-challenged airports in Central America and South America," Terpstra said. "When they made the proposal during one of our airline seminars, we began doing research into whether that really was the best method or whether there were better ways for terrain awareness. As one part of that research, MVA sectors were depicted on some sample area charts and terrain shading was drawn on top of other IFR area charts for Denver [Colorado, U.S.], a mountainous terminal area."

**"One pilot said, 'That's not right — he's got us going right at that terrain' — then the captain refused the vector and corrected the error."**

The company conducted research with airline pilots in McDonnell Douglas DC-10 flight simulators. An instructor-captain conducted test-flight scenarios that included radar vectors around the area for approaches.

"The instructor intentionally gave the crew radar vectors that would direct the aircraft into terrain," Terpstra said. "He then evaluated the crew's ability to visualize whether or not they were within the depicted MVA sector. We found that MVA charts printed over area charts were quite difficult to use and so confusing that they were not of value. Terrain depiction was much more vivid to a pilot compared with interpreting what was on MVA charts. So we added the first colored terrain shading to our IFR area charts in 1976."

The first terrain was depicted as shaded areas called area minimum altitudes (AMAs), providing 1,000 feet of terrain/obstacle clearance for aircraft operating at or below 6,000 feet mean sea level (MSL) and providing 2,000 feet of terrain/obstacle clearance for aircraft operating at 7,000 feet MSL or higher.

Typically, pilots in the test-flight scenarios had difficulty in determining precisely where they were located during radar vectors to determine the MVA sector.

"If crews tried to use VOR DME during radar vectors, determining the MVA sector was almost impossible," Terpstra said. "The principal reason was that the center of the DME was not at the center of the radar-antenna site used to establish the circles, arcs and lines of MVA sectors. We never pursued this application of paper MVA charts with airlines in the United States. That is one of the reasons why there have been no paper MVA charts published for pilots in the United States.

"The intent in countries where MVA charts are published for pilots is to provide meaningful information, but I am not sure how well paper MVA charts work. In the United States, I believe that the main issue was not complexity of MVA charts, but rather the study that found that pilots then had great difficulty interpreting their position relative to the MVA sectors during flight."

## ICAO Cites Ambiguity of Position During Vectoring

The term "minimum radar-vectoring altitude" is used by the International Civil Aviation Organization (ICAO) to describe a predetermined altitude used by ATC units for tactical radar vectoring, but the term is not defined in ICAO *Procedures for Air Navigation Services – Air Traffic Management* (*PANS–ATM,* Document 4444) or in *PANS–Operations* (*PANS–OPS,* Document 8168, Volume II, Part III, Chapter 24, "Procedures Based on Tactical Vectoring"). General principles for providing radar-vectoring information to pilots were recommended by the ICAO 6th Air Navigation Commission in 1969 and by the U.K. Civil Aviation Authority (CAA) Terrain Clearance Working Group in 1976. (Civil aviation authorities may use other terms and definitions in regulations that refer to similar requirements for radar-vectoring IFR aircraft.)

For example, in the United Kingdom, U.K. CAA defines a "radar vectoring area" as "a defined area in the vicinity of an aerodrome, in which the minimum safe levels allocated by a radar controller vectoring IFR flights have been predetermined."[6]

In the United States, the Federal Aviation Administration (FAA) defines MVA as "The lowest MSL [mean sea level] altitude at which IFR aircraft will be vectored by a radar controller, except as otherwise authorized for radar approaches, departures and missed approaches. The altitude meets IFR obstacle criteria. It may be lower than the public MEA [minimum en route IFR altitude] along an airway or J-route [jet route] segment. It may be used for radar vectoring only upon the controller's determination that an adequate radar return is being received from the aircraft being controlled. Charts depicting [MVAs] are normally available only to the controller and not to pilots."[7] FAA defines an "off-route vector" as "a vector used by ATC which takes an aircraft off a previously assigned route. Altitudes assigned by ATC during such vectors provide required obstacle clearance."

**"The intent … is to provide meaningful information, but I am not sure how well paper MVA charts work."**

Other ICAO documents relevant to discussion of pilot awareness of MVAs include the following:

- *PANS–ATM,* Paragraph 8.6.5.2, says, "When vectoring an IFR flight, the radar controller shall issue clearances such that the prescribed obstacle clearance shall exist at all times until the aircraft reaches the point where the pilot will resume own navigation. When necessary, the [MVA] shall include a correction for low-temperature effect. … When an IFR flight is being vectored, the pilot is often unable to determine the aircraft's exact position and consequently the altitude which provides the required obstacle clearance";
- *PANS–ATM,* Paragraph 8.6.8, "Minimum Levels," says, "A radar controller shall at all times be in possession of full and up-to-date information regarding established minimum flight altitudes within the area of responsibility; the lowest usable flight level or levels …; and established minimum altitudes applicable to procedures based on tactical radar vectoring. … Criteria for the determination of minimum altitudes applicable to procedures based on tactical radar vectoring are contained in *Procedures for Air Navigation Services—Aircraft Operations* (*PANS–OPS,* [Document] 8168), Volume II, Part III, [paragraph 24.2.2.3, 'Procedures Based on Tactical Vectoring']";
- *PANS–ATM,* Chapter 4, "General Provisions for Air Traffic Services [ATS]," paragraph 4.10.3, "Minimum Cruising Level for IFR Flights," says, "Except when specifically authorized by the appropriate authority, cruising levels below the minimum flight altitudes established by the state shall not be assigned. … The objectives of air traffic control service as prescribed in [ICAO] Annex 11 [*Air Traffic Services*] do not include the prevention of collision with terrain. The procedures described in this document do not therefore relieve the pilots of their responsibility to ensure that any clearance issued by air traffic control units is safe in this respect, except when an IFR flight is vectored by radar"; and,
- *PANS–ATM,* section 8.3, "Communications," says, "The level of [ATC] reliability and availability of communications systems shall be such that the possibility of system failures or significant degradations is very remote. Adequate backup facilities shall be provided."

*Continued on page 6*

## CHIRP, ASRS Reports Suggest Value of MVA Awareness

The following reports describe circumstances in which pilot awareness of minimum vectoring altitude (MVA) might be beneficial for safety:

- "The air traffic controller [in a previous letter published by CHIRP[1]] asks why the pilot descended below MSA [minimum sector altitude] when asked to do so by ATC [air traffic control]. [The controller said,] 'MSAs are published on the approach plates, so why didn't the crew query the altitude given?' I have heard this one once too often. Pilots descend below MSA on almost every flight they make, as a matter of routine, you would not get into alpine [mountainous] airports any other way. Even in lowland areas like [airport omitted by CHIRP], the MSA is 3,500 [feet] and the usual clearance is to 1,850 [feet]. Some pilots declare the radar-vectoring minima to be a better rule to follow, but not only are the jagged edges of these areas [sectors on U.K. radar-vectoring-area charts] difficult to follow in relation to the aircraft position, but many airports (like Liverpool) regularly descend the aircraft in IMC [instrument meteorological conditions] below the radar-vectoring minima (to 1,500 feet on Runway 9). I noticed a recent incident report that blamed the crew for making a descent below MSA. Yet I seem to remember making many radar-vectored right-base turns onto [Runway] 24 at [airport omitted by CHIRP] that were well below MSA in IMC — simply because the controller wanted to place the aircraft on a quick 7.0-mile final [approach segment]. There are no clear rules as to whether one should follow the clearance below MSA and, while making a mental picture of your position in the circuit [traffic pattern] can assist in making such judgment, if there are any distractions going on at the time, one is very likely to follow the [ATC radar-vector] instruction." (CHIRP Report no. 2406, June 5, 2000)

- "Departure [from European airport omitted by CHIRP] was via SID [standard instrument departure] from Runway 22L, with stop height 4,000 feet. This entails a straight-ahead climb to 4.0 nautical miles [7.4 kilometers] from the [identification omitted by CHIRP] VOR DME, followed by a right turn downwind to pick up a northerly track from the VOR to AAA. The MSA within 25 nautical miles [46 kilometers] to the north of the airfield is 8,500 feet; beyond that, minimum IFR levels [altitudes] rise to Flight Level (FL) 100 [approximately 10,000 feet]. Passing abeam the field on the downwind leg, I thought that further climb might be desirable, as we were heading for this high ground which was partially (say, scattered to broken) cloud covered. After a pause, clearance was given to climb to FL 130. Some moments later, ATC requested whether we were in visual contact with the ground. We were then passing FL 80, VMC [visual meteorological conditions] on top with intermittent ground contact. While under radar control, it is the pilot's responsibility to maintain terrain clearance. With this in mind, I looked at Jeppesen's 'radar vectoring area' chart. While this shows minimum flight levels in various sectors, it does not have a range/radial graticule, making it difficult to use properly. Also, the SID chart does not have minimum en route heights, nor does it have the MSA circle found on the approach plates. Had I not requested the further climb when I did, I dread to think of the consequences. At best, a 'pull up' as I approached the hills. At most, CFIT [controlled flight into terrain] on a turn away from my cleared track, perhaps straight into the opposing traffic? We hear a lot about 'airmanship' — perhaps there should be some talk of 'controllermanship' sometimes." (CHIRP Report no. 2438, July 20, 2000)

- "During flight from San Diego [California, U.S.] International Airport to Ontario [California] International Airport [in a Boeing 757-200], ATC issued clearance to fly heading 275 degrees, radar vector to BONDO intersection, direct HDF, direct PETIS NDB [nondirectional beacon], direct Ontario. Outside PETIS NDB, the crew was given clearance to fly heading 340 degrees for vectors to join Localizer Runway 26L approach to Ontario and a descent to 4,200 feet. After leveling at 4,200 feet, the crew received an EGPWS [enhanced ground-proximity warning system] 'Terrain, Terrain. Pull Up.' warning. The captain, who was the pilot flying, complied and immediately climbed to 5,000 feet where the warning stopped. ATC was notified and the flight proceeded to Ontario with no further [problem]. Upon descent into the Ontario area, the crew had the EGPWS with terrain [warning] activated. The crew saw the terrain ahead of the aircraft and determined that the descent clearance to 4,200 feet was safe and reasonable. The crew believes that terrain was never a [safety] factor but had no choice but to respond to the warning using proper CFIT[-prevention] recovery technique. Both [I] and the first officer do not believe that any other aircraft were placed in jeopardy." (U.S. National Aeronautics and Space Administration [NASA] Aviation Safety Reporting System [ASRS][2] Report no. 614863, April 2004)

- "Upon approach to ILS [instrument landing system] Runway 12R with the copilot flying [a Canadair Regional Jet 200], we were instructed to descend from 3,000 feet to 1,800 feet MSL [mean sea level]. I set 1,800 feet on the altitude alerter … and the copilot verified it. We were about to intercept the localizer for Runway 12R when the controller said, 'Turn to heading 150 degrees at 2,800 feet to join, cleared for the ILS Runway 12R approach. We were passing through 2,800 feet when he [the controller] came back and said that he had a 'low altitude alert, climb immediately' [on the minimum safe altitude warning system of the approach radar]. We complied immediately, leveled at 2,800 feet and completed the approach. The copilot had briefed the approach, and we were aware of the 2,800 feet on the ILS approach. The same controller earlier had offered us a visual [approach] on the downwind. I told him we could not [conduct a visual approach] because we would lose sight of the field during the approach. When he gave us the 1,800 feet [altitude] assignment, we thought that he was giving us an MVA (controller altitude) to get under the clouds for the visual [approach]. We never went to 1,800 feet and never broke out of the clouds. No passengers or crew were affected by the immediate climb to 2,800 feet. (NASA ASRS Report no. 606025, January 2004)

- "The controller next to me gave radar contact to the aircraft at 3,200 feet MSL and cleared the aircraft direct FLAAK for the EPH 6 arrival into Seattle-Tacoma [Washington, U.S.] International Airport. I told the controller that the aircraft was below terrain and the controller took no action. MVA in that area [sector] is 6,000 feet. The supervisor watched this happen and said he would take action. None was taken. The area manager was aware that this happened but wanted to wait and see what action his supervisor was going to take. Almost two weeks after this happened, no one has tried to correct the performance of the [controller]. Peer pressure on this controller has not worked, and vectors below terrain are still given. I have to wonder why no action is taken. Normal operations for this situation would have been 'Leaving 6,000 feet, cleared direct FLAAK, EPH 6 to Seattle." (NASA ASRS Report no. 601609, November 2003) ■

## Notes

1. These reports were selected for Flight Safety Foundation by the CHIRP Charitable Trust, which administers a confidential incident-reporting system in the United Kingdom, and are used with permission. The CHIRP Internet site said, "The objective of CHIRP is to promote safety in the aviation [sector] and maritime sector for employees and others by obtaining, distributing and analyzing safety-related reports which would not otherwise be available, while at all times keeping the identity of the reporter confidential."

2. The U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) is a confidential incident-reporting system. The ASRS *Program Overview* said, "Pilots, air traffic controllers, flight attendants, mechanics, ground personnel and others involved in aviation operations submit reports to the ASRS when they are involved in, or observe, an incident or situation in which aviation safety was compromised. … ASRS de-identifies reports before entering them into the incident database. All personal and organizational names are removed. Dates, times and related information, which could be used to infer an identity, are either generalized or eliminated." ASRS acknowledges that its data have certain limitations. ASRS *Directline* (December 1998) said, "Reporters to ASRS may introduce biases that result from a greater tendency to report serious events than minor ones; from organizational and geographic influences; and from many other factors. All of these potential influences reduce the confidence that can be attached to statistical findings based on ASRS data. However, the proportions of consistently reported incidents to ASRS, such as altitude deviations, have been remarkably stable over many years. Therefore, users of ASRS may presume that incident reports drawn from a time interval of several or more years will reflect patterns that are broadly representative of the total universe of aviation-safety incidents of that type."

U.K. CAA — which began in the early 1970s to publish radar vectoring area (RVA) charts as advisory information for pilots — and FAA — which released in June 2004 radar-video-map (RVM) MVA-chart data files as advisory information for pilots — are moving toward similar practices (Figure 1, page 7). Their methods of developing RVA charts and MVA charts, respectively, will enable these altitudes to be used more effectively in electronic flight deck applications than is possible with paper charts.

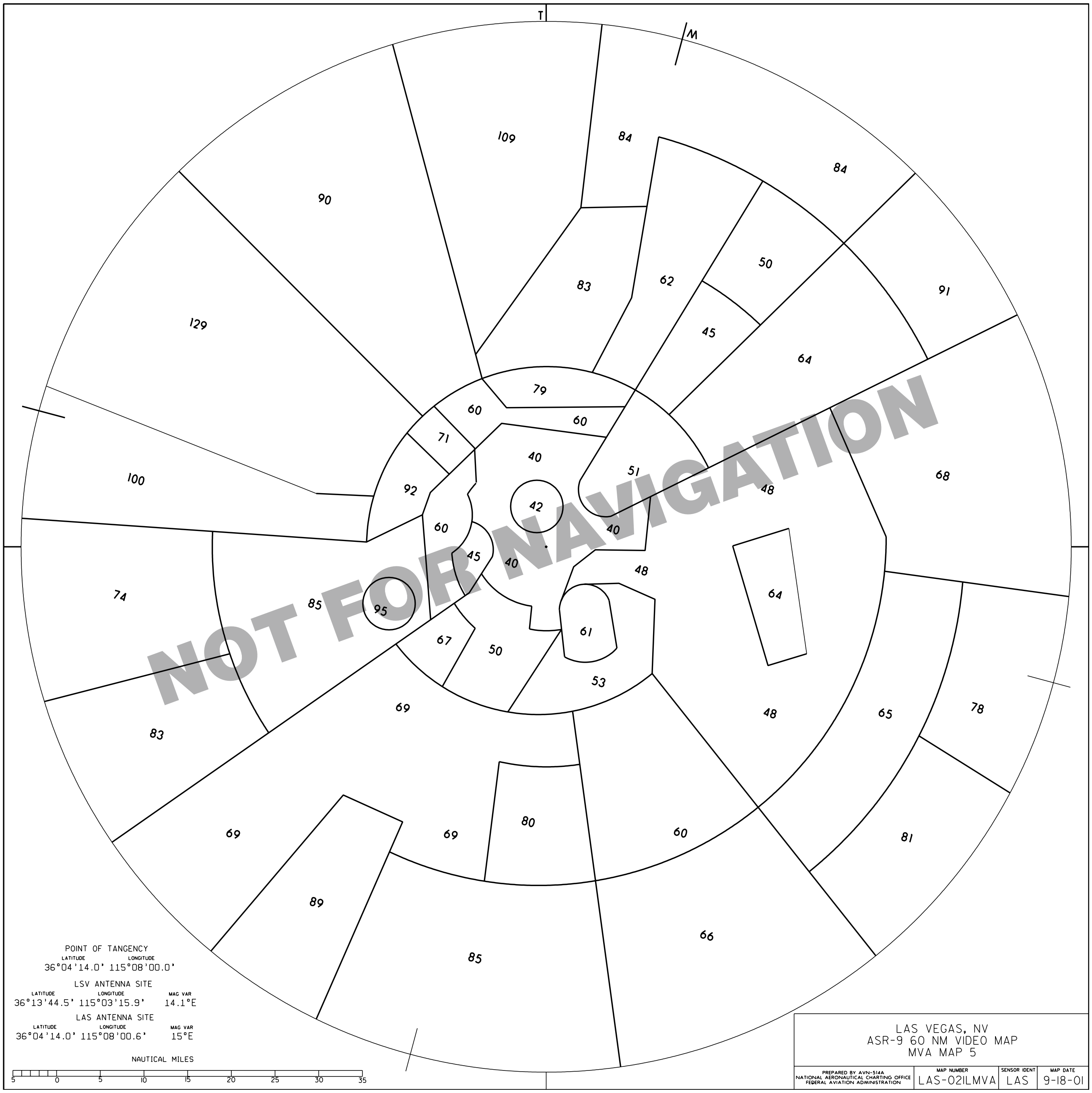
## U.K. CAA Charts Originate With Local ATS Providers

U.K. CAA is responsible for design authority and policies applicable to RVAs. ATS providers are responsible for the design, accuracy, currency and operational application of their RVAs. RVA charts are valid for two years but may be reviewed and suspended/revised if the ATS provider becomes aware of any safety-critical inaccuracy.

The purpose of RVAs is defined in terms of radar controller requirements and pilot requirements. U.K. CAA said that this is

*Continued on page 8*

**Figure 1**
**FAA Radar Video Map–Minimum Vectoring Altitude Chart**
**Las Vegas, Nevada, U.S.**




T = True north M = Magnetic north FAA = U.S. Federal Aviation Administration

Note: The center point is the antenna site for airport surveillance radar and each sector within the circle shows the minimum vectoring altitude for that sector in hundreds of feet.

Source: U.S. Federal Aviation Administration

**"In the 1960s and 1970s, RVA charts capable of ready interpretation were seen as a significant contribution to the prevention of CFIT."**

"to relieve the radar controller of the responsibility for determining the appropriate minimum safe levels, in the vicinity of the aerodrome, where radar sequencing and the separation of arriving IFR flights [are] taking place; and, to provide pilots with an indication of the minimum altitudes at which ATC radar vectoring will take place on initial approach below the published [MSA]. [RVA charts are promulgated in the Aerodrome (AD 2) section of the U.K. *Aeronautical Information Publication.* They will contain suitable information to enable their use by pilots.]"

"It is very important to recognize that the RVA is not the only area within which radar vectoring may take place," U.K. CAA said. "When vectoring flights outside the RVA, the controller is responsible for determining and providing the required terrain clearance as specified in CAP 493 *Manual of Air Traffic Services* Part 1. … RVAs do not constitute controlled airspace nor do they attract any special airspace attention in their own right. The dimensions of the standard RVA … take account of the handling characteristics of modern aircraft and ATC radar-vectoring requirements."

Initial RVA charts are drafted manually and centered on an airport reference point (Figure 2, page 9), not on the radar-antenna site, and working drawings, final drawings and final accuracy checks are done by terminal-airspace specialists. Standard shapes have been developed for airports with a single instrument runway and multiple instrument runways.

U.K. aeronautical topographical charts (1.0 inch: 250,000 feet [1.0 centimeter: 30,000 meter] scale), which depict obstacles above 300 feet AGL, are used in initial RVA chart development and other data sources with more detail are used to validate/refine required obstruction clearances during chart preparation. Published RVAs do not conform to a fixed scale, but depict a 10-nautical-mile scale bar. U.K. radar-vectoring terrain-clearance requirements also provide a safety margin for unknown obstacles below 300 feet AGL and for altimeter error.

Under U.K. CAA's terrain-clearance criteria for RVAs, the minimum altitude available for radar-vectoring arriving flights within the RVA is 1,000 feet above the highest obstacle within the RVA or RVA sector. "Design rules also specify that the minimum altitude for any RVA or RVA sector will not be less than 1,500 feet in compliance with the U.K. requirement that aircraft shall be vectored to join final approach at not less than 5.0 nautical miles (8.0 kilometers) from touchdown," U.K. CAA said. Additional criteria specify buffer areas used to factor in obstacles in the vicinity of the standard-shape RVA and to determine the minimum altitude for ATC use. Design methods require ATC when creating RVA sectors to consider the ability of pilots to determine their position. RVAs also must conform to regulations governing low-altitude flight operations.

"Where operationally desirable, the RVA may be sectorized to provide relief from dominant obstacles that would affect only one runway direction or radar circuit," U.K. CAA said. "Sectorization should, whenever practicable, be referenced to navigation aids (to provide ease of cross-checking by flight crew). When considering sectorization of the RVA, complex sectorizations, which might be difficult for flight crew or controllers to assimilate, should be avoided. Instrument approach procedure (IAP) MSAs shall be shown on RVA charts to indicate the minimum level that should be attained by aircraft intentionally leaving the RVA."

In practice, U.K. radar controllers must ensure that radar coverage is adequate before issuing instructions to descend to RVA altitudes, and they must apply greater terrain/obstacle clearance requirements defined in the *Manual of Air Traffic Services* when aircraft are more than 30 nautical miles (48 kilometers) from the radar-antenna site on which the RVA is based. "This basically requires the radar controller to maintain 1,000 feet vertically above the highest fixed object in a keyhole-shaped area around and ahead of the aircraft," said Martyn Cooper, a representative of U.K. CAA.[8]

"In the 1960s and 1970s, RVA charts capable of ready interpretation were seen as a significant contribution to the prevention of CFIT," Cooper said. "As a consequence of a terrain-related accident involving a U.K. public transport aircraft in 1974, the U.K. Terrain Clearance Working Group

*Continued on page 10*

**Figure 2**
**Example of U.K. CAA Radar Vectoring Area Chart**
**Norwich International Airport, Norwich, England, U.K.**

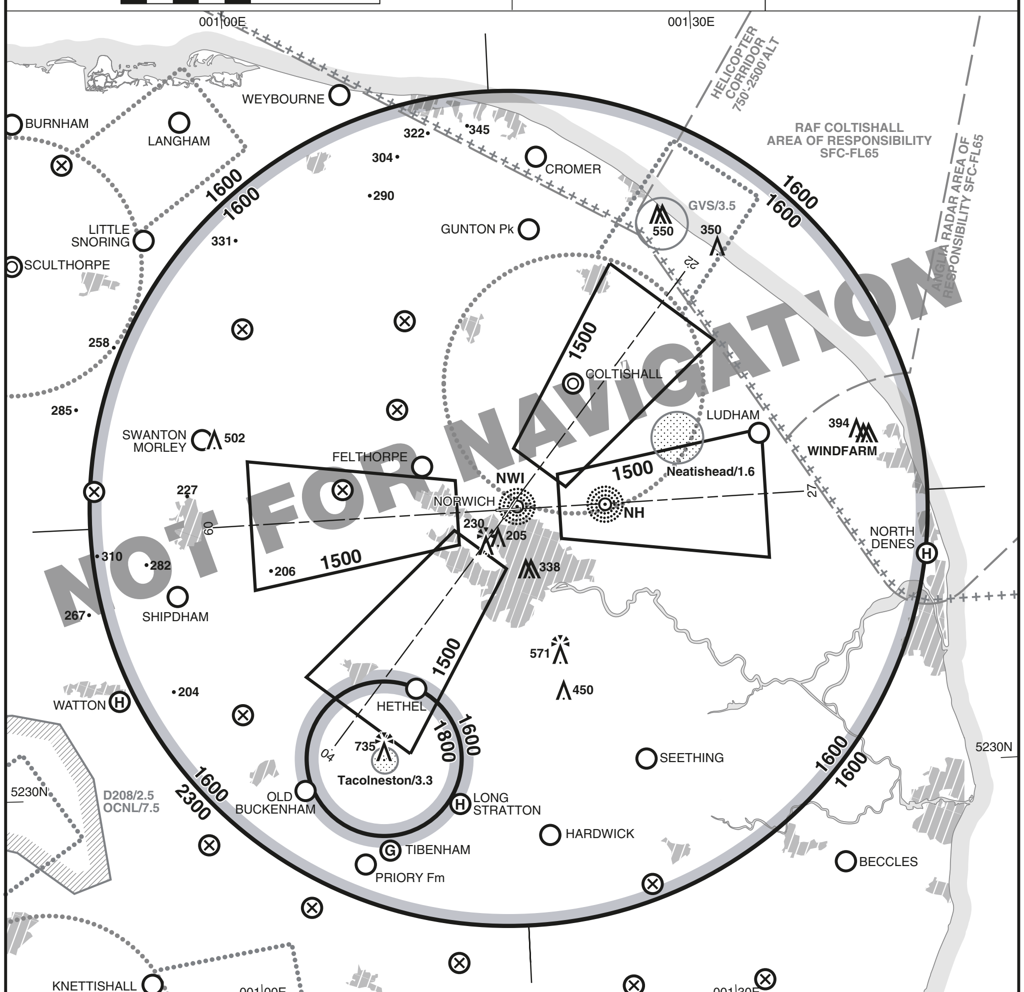
**UK AIP** **(25 Dec 03) AD 2-EGSH-5-1**

## RADAR VECTORING AREA — NORWICH

GENERAL INFORMATION
1. All bearings are magnetic.
2. Levels shown are based on QNH.
3. Only significant obstacles and dominant spot heights are shown.
4. The minimum levels shown within the Radar Vectoring Area ensure terrain clearance in conformity with Rule 29 of the Rules of the Air Regulations in respect of obstacles within the RVA.
5. Minimum Sector Altitudes are based on obstacles and spot heights within 25NM of the Aerodrome Reference Point.

Within the Radar Vectoring Area the minimum initial altitude to be allocated by the radar controller is 1600FT except within 3NM of Talcolneston (735FT amsl) where the minimum initial altitude to be allocated is 1800FT. Further descent to 1500FT may be given within the Approach Areas shown when on 40° leg or Final Approach.

0 1 2 3 4 5 10NM | **Elevation 117FT** | **Transition ALT 3000FT**




**LOSS OF COMMUNICATION PROCEDURES**

**Initial Approach**
Continue visually or by means of an appropriate final approach aid. If not possible proceed at 2000FT, or last assigned level if higher, to NDB(L) NH†.

**Intermediate and Final Approach**
Continue visually or by means of an appropriate final approach aid. If not possible follow the Missed Approach Procedure to NDB(L) NH†.

† In all cases where the aircraft returns to the holding facility the procedure to be adopted is the basic Radio Failure Procedure detailed at ENR 1.1.3.

**CHANGE** NEW RVA DIMENSIONS. APPROACH AREA. MSA TO SW.

AERO INFO DATE 16 OCT 03

Civil Aviation Authority — AMDT AIRAC 13/03

Source: U.K. Civil Aviation Authority

considered the then-extant RVA parameters. The conclusion was that the radar controller's main responsibility was to separate and sequence traffic, and that a separate method should be employed to determine and publish the minimal initial altitudes that a controller will allocate.

"The working group reaffirmed that minimum (terrain-safe) levels available to controllers should be predetermined — that is, not left to controllers to work out for themselves — and that this information should be available to pilots. ICAO *PANS–OPS,* following the U.K. lead, introduced procedures based on tactical radar vectoring in the early 1980s. Recently, an enhanced RVA-design process and a requirement for regular design review have been applied to U.K. aerodrome operators and to ATS providers. The design responsibility has been transferred from a central authority to local management of ATS. "

U.K. CAA guidance for air carriers describes the responsibility of air carrier pilots for terrain clearance but does not explicitly require that they use RVA charts, Cooper said.

"CAP 360, *Air Operator's Certificate – Operation of Aircraft,* describes the responsibilities of aircraft operators in respect of flight deck documentation," he said. "However, it is stated that 'when under radar control, it is their responsibility [i.e., the responsibility of commanders of aircraft] to ensure adequate terrain clearance. CAP 360 is not law, and failure to comply with CAP 360 is not an offense. Our meaning in the guidance is that commanders have this responsibility, and this means that how they choose to discharge it is up to them. Although unsaid, their actions should be in line with current practice, recommendations and/or good airmanship. They could, for example, use RVA charts. RVAs assist the aircrew's situational awareness, and RVA charts should trigger a response/reaction by the aircrew if an abnormal level is assigned by a controller."

All U.K. RVA charts are available in digital format from commercial sources with the same content and detail as paper RVA charts. They currently can be used in electronic flight bags (EFBs)[9] that are compatible with electronic charts, Cooper said. "Currently, U.K. CAA does not publish RVA-chart data as individual RVA dimensions/sectorizations in latitude/longitude format," he said.

## FAA MVA Charts Involve Centralized Accuracy Checks

Unlike U.K. ATS providers, FAA ATC facilities design their MVA charts for use by radar controllers — with each MVA chart centered on the location of the radar-antenna site. FAA design criteria vary depending on whether the MVA chart is for terminal-control services and/or approach-control services with airport surveillance radar (ASR), with ASR plus air route surveillance radar (ASRS) as a backup radar system or with ASRS. MVAs may be drawn to the maximum ASR radar range or ASRS radar range (typically 60 nautical miles [97 kilometers]) or drawn to a 40-nautical-mile [64-kilometer] range from the radar-antenna site with MVAs, en route minimum IFR altitudes (MIAs) or a combination as specified by FAA Order 7210.3T, *Facility Operation and Administration.*[10]

FAA ATC facilities use paper sectional aeronautical charts (or computer-generated substitutes of required accuracy and scale) to develop their initial MVA chart design or revisions. Techniques for depicting sectors within the RVM MVA chart include the use of magnetic bearings from the antenna site, radials from VORs/VORTACs/TACANs [tactical air navigation] or radar-display range marks. MVA boundaries coincide with, or are compatible with, map overlays or RVM data on radar displays.

Principles of MVA design include making sectors large enough to accommodate radar vectoring of aircraft and creating area boundaries from each obstruction of 3.0 nautical miles (for obstacles less than 40 nautical miles (74 kilometers) from the radar-antenna site) to 5.0 nautical miles (9.3 kilometers, for obstacles 40 nautical miles or more from the radar-antenna site), and enclosing single prominent obstructions with buffers (as done for area boundaries) to facilitate radar vectoring of aircraft around the obstruction.

The required-obstacle-clearance criteria from FAA Order 8260.19, *Flight Procedures and Airspace,* then are applied to each RVM MVA-chart sector. The altitudes normally are not less than MIA vertical obstacle clearance: 1,000 feet in nonmountainous areas or 2,000 feet in the designated mountainous areas of the United States that are defined in Federal Aviation Regulations (FARs) Part 95, *IFR Altitudes.*

"MVAs are established irrespective of the flight-checked radar coverage in the sector concerned," FAA said. "They are based on obstruction clearance only. It is the responsibility of the controller to determine that a target return is adequate for radar-control purposes." Designers also ensure that MVAs on MVA charts are compatible with vectoring altitudes established for radar instrument approach procedures.

Current FAA specifications for MVA charts require review at least annually, and charts must be revised immediately when changes occur that would affect MVAs. Reviews and approvals of initial MVA charts and revised MVA charts are conducted by FAA's National Flight Procedures Office, and final charts are produced by FAA's National Aeronautical Charting Office (NACO) as video maps in various NACO ATC-data formats for radar displays and as RVM MVA chart-data files (see "Internet Offers Subscribers Access to MVA-chart Data," page 16).

The following recent changes affect how U.S. RVM MVA charts are developed and used:

- In 2004, FAA initiated policy changes for the development of MVA charts in FAA Order 8260.19; initiated changes in its MVA chart development, review and approval process; and released RVM MVA-chart data files to the public (see "Industry Innovations Expected for MVAs," page 13);

- Comprehensive, updated criteria for the design of MVA charts were prepared in 2003 for the pending Change 20 to FAA Order 8260.3, *U.S. Standard for Terminal Instrument Procedures* (TERPS);

- Work continued on procurement of an automated tool for use in the development and approval of MVA charts and MIA charts (used by air route traffic control centers in controlled airspace without radar coverage);

- Internal review of current FAA policy and orders that allow reductions, under specific criteria, of MVA-required obstacle clearance from the standard 2,000 feet in designated mountainous areas was underway in 2004; and,

- FAA radar controllers have been reminded that pilots typically have no immediate knowledge of the minimum assignable altitude because ATC may utilize diverse vector areas, MVAs and other altitudes authorized by FAA Order 7110.65P, *Air Traffic Control*.

## NBAA Leads Quest for FAA MVA-chart Data

U.S. MVA charts evolved for use exclusively by ATC in part because no practical methods existed to integrate MVA information into the flight deck, said Bob Lamond, director of air traffic services and infrastructure, U.S. National Business Aviation Association (NBAA).[11]

"About three years ago, however, the NBAA Flight Management System Subcommittee saw an opportunity to take advantage of existing technology to improve pilots' situational awareness related to MVAs and MIAs — without introducing new problems," Lamond said. "The subcommittee found a few documented incidents in which airplanes came very close to CFIT as a result of lack of adequate situational awareness. Some pilots were distracted while operating in clouds and did not realize immediately that they were approaching higher terrain. Consequently, we began questioning why U.S. MVA data should not be available to pilots."

What also occurred sometimes in a busy departure environment or in a busy arrival environment was that the controller intended to issue a timely radar vector to turn or climb but the instruction was delayed by radio-frequency congestion or other cause, he said.

"Crews currently may have no reason to question the absence of further radar vectors while operating at the MVA — they may not realize that they have gone through a sector into a sector with a higher MVA," Lamond said.

During an August 2003 meeting, FAA representatives and industry representatives discussed the public availability of MVA/MIA charts, the fidelity of charts in use, the criteria and policy under which charts are developed, and the legal requirements for pilots of FARs Part 91.175 and Part 91.177 as they relate to MVA/MIA charts.[12,13]

Lamond said that NBAA and other organizations worked with FAA to address concerns that:

- Pilots/operators might use MVA-chart data for purposes other than advisory information (e.g., the files must *not* be used as a navigational tool);

- Availability of MVA data in the cockpit might generate unwarranted/unsafe questioning of ATC radar vectors;

- Uncontrolled distribution of MVA-chart data would result in unsafe use of the data (unlike the strictly controlled application of MVA data within ATC);

- Distribution could be technically complex and/or costly to implement;

- Release of RVM MVA-chart data would result in legal liability issues; and,

- Safety risks might be involved in changing proven methods.

Robert H. Vandel, FSF executive vice president, in December 2003 co-signed with NBAA and the Air Line Pilots Association, International, a letter to FAA. The letter requested the release of MVA-chart data to qualified original equipment manufacturers that request the data for use as advisory information.

"We are continuing to work with FAA to develop a framework of manufacturer standards and operational guidelines by early 2005," Lamond said. "NBAA simply sees MVA charts as one more set of background data to help warn pilots before they fly into harm's way. This is critical information, but using MVA data alone will not be a silver bullet [i.e., a complete solution] for CFIT prevention."

Capt. Wally Roberts, an advisor to NBAA and proponent of flight deck applications of MVA-chart data, said that some MVA charts used by U.S. ATC facilities in mountainous areas have become highly complex — for example, showing many small sectors relatively compressed against steeply rising terrain.[14]

"In mountainous, high-traffic areas such as Reno and Las Vegas, Nevada, and Los

Angeles, California, some MVA sectors have evolved into complex, convoluted polygons rather than simple segments at various ranges from the radar-antenna site," he said. "Complex sectors have been designed partly to provide versatility in aircraft separation and traffic flow, and ATC cannot be faulted for designing orderly transitions to approach procedures.

"They are unlike typical sectors in nonmountainous areas of the United States or in Europe, where sectors are based on a five-mile or 10-mile radar range that is very simple to video-map and to understand. Complex sectors very easily would become time-consuming — not enabling — for pilots. The problem will be not so much that these sectors are complex, but how to provide MVA-chart data that are readily usable, scalable and georeferenced to the aircraft position."

San Diego, California, was among MVA charts reviewed by Roberts that supports his belief that pilots will require scalable electronic MVA charts as advisory information on the flight deck.

"San Diego, if scaled to the working area of interest, is very straightforward to read," Roberts said. "If depicted on a paper chart, however, it would be unreadable to pilots in flight. As designed for FAA ATC — showing a circle of 120-nautical-mile [193-kilometer] diameter — paper MVA charts would be useless and inappropriate from a human factors standpoint, causing information overload and confusion. It would take pilots too much time to make sense out of these MVA charts on paper — pilots would not use them."

**Giving pilots access to MVA-chart data will not be a "sea change" in the traditional pilot–controller relationship.**

Nevertheless, technology already used for flight deck display of other advisory information shows promise for capabilities such as dynamic altitude symbology — i.e., keeping the altitude number visible and correctly oriented for each MVA sector, he said. Otherwise, if an electronic MVA chart scrolls off a pilot's display, sector altitudes also disappear from the display.

Based on Roberts' experimentation with FAA's RVM MVA-chart data files, public availability of the data files also might support applications such as the following:

- Research on problems in specific airport approaches and departures; TAWS terrain warnings; and anomalies during radar vectoring;
- Creation of MVA-sector overlays on large wall charts of airport terminal areas for general advisory and educational purposes;
- Pilot training on MVAs using real airport MVA charts in place of simulated example charts;
- Airport-familiarization briefings; and,
- Preflight review by pilots for a general awareness of the MVAs in the terminal area.

Looking at an FAA MVA chart, as designed for ATC use, enables the pilot to see the lowest and highest MVAs, the altitude changes between adjacent MVA sectors, sectors where an MVA is significantly higher than the average MVAs and the relative positions of MVA sectors.

When an MVA chart is superimposed correctly on a sectional aeronautical chart (which depicts terrain and the floors of controlled airspace), the pilot can see MVA sectors and MVAs relative to terrain and relative to navaids, fixes, low-altitude Victor airways, obstacles and the airport's highest nearby terrain. When an MVA chart is superimposed correctly on an IFR area chart, approach chart, standard terminal arrival procedure or departure procedure, the pilot can see how MVAs compare with altitudes such as MEAs, minimum obstruction-clearance altitudes (MOCAs) and MSAs.

Giving pilots access to MVA-chart data will not be a "sea change" in the traditional pilot–controller relationship, said Steve Bergner, chairman of NBAA's FMS Subcommittee and chief pilot for Cable Air of White Lake, New York, U.S.[15]

"I do see MVA cross-checking as a way to bring situational awareness and operational safety up several notches during radar-vectored operations and radar-monitored direct-to RNAV operations," Bergner said. "The controller will have the lead during radar vectors and the pilot will not be doing the navigation per se — even though an electronic MVA chart will be in the cockpit."

With increasing use of RNAV, which inherently involves random routing, U.S. pilots more often leave the safety of a published IFR route or IFR procedure than in the past, he said.

"As we get into more and more random operations, we are losing some of our anti-CFIT IFR safety net — the MEAs, MOCAS and published IFR routes," Bergner said. "Availability of electronic MVA charts in the cockpit will help to restore the safety net."

Published RNAV waypoints on a departure, for example, may be in an A-B-C-D sequence, but if the tactical situation permits, ATC may find it more efficient to clear the airplane direct to downstream waypoint D from waypoint A, he said.

"Controllers need the tactical flexibility to take airplanes off a published route to establish a sequence or the necessary spacing," Bergner said. "We all want the same IFR safety margins — irrespective of the phase of flight — from MVA charts. Pilots intuitively want this whenever airplanes are relatively close to the ground during terminal operations, so the same IFR-charting science ought to apply. Whether the airplane is on the black line of a chart or an ATC-assigned heading, the required-obstacle-clearance values and integrity of obstacle clearance should be applied for MVA/MIA charts as for airways and feeder routes."

In flight, access to MVA data will provide the pilot an additional measure of confidence while being radar-vectored in unfamiliar areas or at night, and will enhance situational awareness when being vectored toward areas of higher terrain or toward higher MVAs, he said.

"Knowing the terrain is easier for pilots in some places than others," Bergner said. "Pilots arriving at some U.S. airports typically face the rather uncomfortable feeling of leaving an MEA structure that is higher than 10,000 feet, for example, and being radar-vectored at low altitudes that are not published on any cockpit reference."

In the era of round-dial cockpits when pilots had only VOR azimuth and DME, the VOR DME typically was not colocated with the ASR site, so they would have had difficulty reconciling aircraft position with MVA sectors.

"As noted by the FSF ALAR Task Force, the introduction of electronic MVA charts with own-ship position [i.e., the position of the aircraft with this display] would allow the pilot to see the position of the airplane relative to the MVA sectors and to zoom in to clearly see the depiction of smaller sectors," Bergner said. "Crossing the finish line on this initiative will be up to the avionics manufacturers and the navigation-database providers. I believe that when pilots have this tool, however, they will not have to lean quite so heavily on the TAWS as the safety system of last resort."

**"Crossing the finish line on this initiative will be up to the avionics manufacturers and the navigation-database providers."**

NBAA's two primary concerns in seeking release of MVA-chart data were the fallibility of radar controllers and the fragility of the very-high-frequency (VHF) communication link, he said.

"Risks multiply whenever the airplane is being radar-vectored close to terrain and is being taken off a published route," Bergner said. "The sole source of minimum safe altitude — VHF radio communication — becomes subject to weaknesses such as misheard/misread clearances, frequencies blocked and misinterpreted call signs."

NBAA would not have an objection to commercial publication of paper MVA charts in addition to electronic applications of RVM MVA-chart data, but the best use of MVA-chart data will be in the moving-map-display technology, he said. Either a paper MVA chart or an electronic MVA chart, however, can help pilots to know before departure what minimum altitudes ATC may use during radar vectoring and can reduce the pilot's anxiety during radar vectoring at some locations, Bergner said.

## Industry Innovations Expected for MVAs

Public release of U.S. RVM MVA-chart data in 2004 culminates two years of discussion through the Government/Industry Aeronautical Charting Forum, said Howard Swancy, senior advisor to the deputy administrator, FAA. "Our position has been that RVM MVA-chart data are part of an internal government system — a radar-controller tool — in support of government employees who provide services to the public. The idea of providing MVA data for advisory information only was a breakthrough — not so much a change in policy as an evolution of policy on what more can be done with the data. The user groups are satisfied, and I would like to keep the momentum going."[16,17]

Part of the inertia that worked against this change in the status quo was FAA specialists' confidence in the current system, Swancy said. "There had not been an earlier identified need to change procedures that largely have been deemed as safe by FAA," he said.

During discussions of potential MVA-chart-data applications on the flight deck, some FAA specialists also saw the absence of policies, procedures or specific aircrew training as a barrier to MVA-chart-data release. How to offer MVA-chart data for something other than directly controlling traffic or for other than mandatory use of these data in flight operations was not grasped easily.

FAA officials reached their decision after weighing the advantages and disadvantages of MVA-chart improvements without publicly releasing data versus MVA-chart improvements with collaborative sharing of information that could enhance situational awareness of pilots, he said.

"We basically concurred with industry representatives that technology being developed possibly would make our old arguments moot because new factors would have to be taken into consideration," Swancy said. "We first had to agree to be open to the concept suggested by the users — FAA changed its position primarily because of better understanding of what users wanted and better understanding by users of what FAA would be able to do. Moreover, we are constrained in the availability of resources to jump out in the lead on MVA applications or to provide a total service. Working with industry organizations, however, we will put in place something that works. We recognized together that there is further utility in RVM MVA-chart data, and that we need to explore that to understand how and if it can be used more efficiently as a flight deck resource."

FAA's decision sets the stage for users of MVA-chart data to investigate applications and perhaps to frame a different concept of pilot situational awareness during radar vectoring.

"The idea of providing MVA data for advisory information only was a breakthrough."

"We want to ensure that future controller procedures and pilot procedures clearly will identify what the roles and responsibilities would be — that is going to be very critical," he said. "In some cases, pilots would have an opportunity, if there were a human error, to provide a second check and to raise a question with ATC. This concept already is in all our flight operations procedures — the pilot being the sole authority for the operation of the aircraft, required to follow ATC instructions but to ask questions and/or to report deviations from clearances when he or she assumes that an instruction will cause an unsafe condition for the airplane. We envision MVA applications for advisory information being no different."

Significant FAA resources have been committed to more effectively adapting databases — such as those containing satellite imagery — from various federal government sources to improve aviation safety.

"In the past several years, there have been changes in our understanding of how to manage differences in terrain data and man-made-obstruction data," Swancy said. "To go beyond the application of RVM MVA-chart data solely as advisory information would require identifying the accuracy requirement for in-flight use with aircraft and how that accuracy requirement corresponds with the accuracy FAA currently provides for ATC use."

FAA's initial MVA-chart development methods and revision methods are being reinforced by satellite imagery, surveys and obstruction-tracking activities.

"All aeronautical charting methods, however, involve some degree of error — we recognize this and factor into FAA processes the errors inherent in charts and in-flight systems," Swancy said. "The working principle is to err on the side of safety by using wider-based assumptions for flight operations so that we do not have a criticality of accuracy down to minute numbers. There have to be built-in safety allowances in the development of MVA charts."

A separate problem for FAA is identifying errors in the interpretation of MVA policy.

"For example, in mountainous terrain, FAA has a basic standard of 2,000 feet of required obstacle clearance, but certain exceptions are allowed in specific instances for less than 2,000 feet," he said. "We currently are having internal arguments and discussions with users and the U.S. National Transportation Safety Board about policy interpretation as to when the exceptions to required obstacle clearance can be used. Some believe that the FARs stipulate that an exception only should be allowed in association with the development of an airway. We expect fairly soon to resolve this policy-interpretation issue."

FAA expects to work with the industry to broadly agree on what types of regulations would be in play and how the pilot using MVAs in a future-flight-operations scenario would be held responsible.

"If you told me that as a pilot I would be operating in an environment where I have operational use of MVAs yet I still receive services provided by ATC, and I still have an obligation to follow clearances, I would want to understand how this affects my reaction to situations based on MVA data," Swancy said. "We have had to work through similar problems — such as the initial implementation of TCAS [traffic alert and collision avoidance system] — where the pilot receives first-hand information that may be contradictory to the controller's information and instructions. But I do not think it would be a difficult thing to work though this issue for future MVA applications."

Companies, organizations and individuals can obtain the RVM MVA-chart data in the same manner, in an FAA file format, he said.

"Anyone interested may contact us and sign up to become a subscriber," he said (see "Internet Offers Subscribers Access to MVA-chart Data," page 16). "Subscribers will be able to manipulate the data in many different media and software applications with the opportunity to use it in any way they see fit. Distributing one file format via an Internet site helps to control FAA's cost compared with trying to support many different software applications without a clear idea of what direction subscribers might be going. FAA meanwhile can validate what we are doing with current MVA-related programs, can determine the full scope and scale of releasing MVA/MIA data under this collaborative controller–pilot concept and can assess related flight systems and/or ground-based systems. Then we could begin the appropriations process to get funding dedicated to the MVA initiative."

Swancy said that every subscriber must read and abide by the disclaimer that FAA has included on the files. There are no restrictions on who can obtain the data, but FAA set up Internet access with the expectation that there would be a low demand from the public.

**"Subscribers will be able to manipulate the data … to use it in any way they see fit."**

Roberts, for example, has used commercial off-the-shelf software for drawing maps, which directly opens FAA's RVM MVA-chart data file as a viewable/printable MVA chart and accurately overlays digital MVA charts onto digital navigational charts with the required center point, scale and orientation to true/magnetic north. (FAA provides paper MVA charts to some ATC facilities as Adobe portable document format [PDF] documents for nonoperational uses such as controller training. Users other than FAA personnel can convert RVM MVA-chart data files to PDF with Adobe software that enables printing paper MVA charts and viewing charts on the display of a personal computer that does not have specialized map-drawing software.)

"Georeferenced MVA charts [i.e., charts containing accurate longitude/latitude data] will be very useful and will greatly enhance safety," Roberts said. FAA's MVA charts show precisely the MVA sectors and corresponding altitudes that radar controllers use because they contain the identical latitude/longitude that NACO uses to produce RVMs for ATC radar displays.

"From initial discussions with industry, FAA understood that current providers of in-flight information could use our files either to produce paper MVA charts suitable for pilots or to adapt them to avionics systems and EFBs," Swancy said. "My expectation is that manufacturers first will be going through the process of certification of systems that will provide an airplane spotter [i.e., a delta-shaped symbol superimposed on the electronic chart to represent own-ship position in real time] overlaid on electronic MVA charts. We assume that many avionics vendors and others who develop in-flight systems will be interested; we also assume that organizations responsible for navigation charts and in-flight databases will be interested. If demand grows, we will work with NACO if there is a need to change the distribution venue."

If subscribers want to use MVA-chart data for purposes such as commercial sale, as a service or for research and development, the disclaimer on each file reinforces the requirement that the only authorized use is for advisory information.

"Not being aware of how subscribers might make changes to MVA-chart data based on their need, and not being able to create standards in advance, the disclaimer seemed reasonable," Swancy said. "The disclaimer also is a self-check to make sure the all users of the data — before they provide services — understand

"These MVA map files are ... not to be used as a navigational tool."

that if they want to change the data use to anything outside of 'advisory-information only,' that they go through the proper process to make sure that they receive FAA certification. At some future date, we probably will have microcomputer technology that will be able to store on the aircraft every terrain height, obstruction and obstacle in the world so that pilots flying in a truly direct-route environment could go anywhere they want and still have real-time situational awareness of terrain and obstacles. MVA-chart data provide a good compromise for the limitations and capabilities that we have today."

## Internet Offers Subscribers Access to MVA-chart Data

FAA's complete set of 374 RVM MVA chart-data files (total as of Sept. 4, 2004) is available to the public via a 24-hour Internet file-transfer-protocol (FTP) site. The site displays a directory of filenames and enables subscribers to download any or all files with web-browser software. File sizes range from about 150 kilobytes to 800 kilobytes. Prospective users must register as a subscriber — by sending an e-mail request to Fred Milburn, fred.milburn@faa.gov — to obtain access to these files, said Terry Laydon, manager of NACO.[18] Access to the FTP site requires a user name and password. File names begin with a three-letter identifier assigned by FAA.

"The password-controlled FTP site was established to enable NACO to have a secure site for users to access these files," Laydon said. "The data in each ASCII [American Standard Code for Information Interchange, a standard used for character-set encoding in computers] file are in FAA's line-geographic-position format or 'line GP' — one of the standard ATC-data formats created by NACO.

"Basically, commands and data in each file enable software to draw lines from point to point, with each point defined by latitude/longitude coordinates. A 'line' command completes each line defined by the points. Each data file includes a header that contains the RVM MVA map number, the date the file was processed and the FAA disclaimer. NACO only updates a file when changes approved by the National Flight Procedures Office are sent from an ATC facility." All elements of an MVA chart, including numbers and words, are drawn as scalable vector graphics (i.e., not editable text). NACO does not charge subscribers for the RVM MVA-chart data.

Each data file contains the following FAA message to the user:

- "MVA charts are not updated on a regularly scheduled cycle. Any person using these files is responsible for checking currency dates on these individual MVA map files;
- "[FAA NACO] certifies the MVA line GP data that is loaded onto the FTP site. Once the files are retrieved, if they are modified, the certification of these MVA map files is no longer valid;
- "These MVA map files are to be used as a visual reference; they are not to be used as a navigational tool;
- "Air traffic control facilities are responsible for the annual review of MVAs; [and,]
- "MVA-chart discrepancies should be reported to the responsible facility in question."

"Pilots are to use MVA charts as an information tool only for CFIT prevention and not as a means for selecting altitudes when filing flight plans, requesting specific altitudes or en route flight," said Tom Schneider, an FAA terminal instrument procedures specialist. "No current operational practices are affected. Material for the FAA *Aeronautical Information Manual* and other pilot-education material are to be developed." Possible regulatory amendments to FARs Part 91.177 are still to be developed by FAA Flight Standards, FAA Air Traffic Services and the FAA Office of General Counsel to clarify that for pilots, acceptance of a radar vector creates an exception to adherence to the IFR minimum altitudes, he said.[19]

"Among proposed changes in TERPS Change 20, no criteria are considered for vectors below the MVA other then the criterion necessary for departures," Schneider said. "Significant changes include a mandatory requirement that the MVA must be at or above the floor of controlled airspace, the consideration of an assumed 200-foot obstacle over terrain and criteria for an adverse-terrain adjustment when terrain contour lines are the controlling obstacle. The primary goal of these initiatives is to have comprehensive MVA criteria in TERPS rather than scattered in several criteria and policy orders."

U.S. air traffic controllers typically have MVA charts printed on translucent vellum overlays available as a backup if the MVA video map fails on a radar display, he said.

The automated system under development would enable digital MVA charts to be drafted first within ATC facilities. The proposed system will use, in addition to digital sectional aeronautical charts, digitized terrain-elevation data and the vertical-obstruction file maintained by NACO, Schneider said.

"This system, when completed, should provide much greater accuracy than the current manual-search method to identify terrain and obstacles on sectional aeronautical charts," he said. "It will provide automated terrain in greater detail than sectional aeronautical charts and will consider man-made obstacles less than 200 feet [61 meters] above ground level. Currently, ATC-facility specialists follow procedures for using more-detailed maps to gain better resolution when terrain data are questionable. The new tool should eliminate or reduce the human-factors errors associated with manual drawing and scanning."

## Adding MVAs to FMS Might Take Years

Terpstra said that within the ACF, discussions about methods of improving MVA-chart development gradually have evolved to conceptualization of methods to incorporate MVA charts into current and future avionics.

"Once pilots have the abilities to know that they are inside a particular MVA sector and to know what the minimum altitude is, MVA data has meaning — they have something that will be helpful from a pilot perspective," he said. "We often hear that pilots 'never run into anything they can see.' Anything we can do to help the pilot to become more aware of where he or she is with respect to terrain is helpful. In general aviation, some avionics equipment for VFR operations already can alert the pilot that the aircraft is near Class B airspace, for example."

Electronic MVA charts will provide pilots a tool to become more aware of terrain by knowing exactly how the aircraft is being vectored in relation to MVA sectors, Terpstra said.

"Preventing the few CFIT accidents where controllers have mistakenly radar-vectored an aircraft into terrain will be the greatest benefit — enabling the pilot to have a check-and-balance with controller-issued vectoring altitudes," he said. "Electronic MVA charts — as a means of validation — will be one of the better safety tools that pilots have had in a long time. Controllers rarely make operational errors, but it is wise for pilots to use the philosophy 'Get a clearance and validate' — have healthy skepticism. Pilots should check that information in every clearance is correct before accepting it. Validation simply is recognition that controllers and pilots are human and do make mistakes."

Jeppesen navigational databases have not been designed specifically to make use of electronic MVA charts. From the perspective of a database manufacturer, however, MVA displays and related functions could be added by several possible methods, Terpstra said. Jeppesen is investigating the ability to deliver MVA data soon to enable some avionics manufacturers to display MVA charts as advisory information in the near future. If deemed appropriate, the international standard for navigation databases (ARINC 424) could be updated in the future.

"General aviation avionics typically will accept more readily new database specifications because they have different kinds of certification requirements than Airbus avionics or Boeing avionics," he said. When air carrier flight decks might incorporate electronic MVA data — especially in the FMS — is more difficult to estimate.

There are a number of methods of presenting MVAs to pilots in the cockpit: some of these include

**"We often hear that pilots 'never run into anything they can see.'"**

paper charts, EFB moving maps FMSs, and navigation displays.

"We may not see any MVA data in the FMS of an airliner flight deck for quite a few years, because of the expense of FMS-specification changes," he said. "I doubt that we would see this in the FMS of the current generation of glass cockpits because of the tremendous cost involved in modifying the avionics. More likely, we might see MVAs in EFBs as they are installed as either forward fits or retrofits.

"The Boeing 777, for example, probably would not be able to have MVA functions in its FMS but some of these airplanes — such those delivered to KLM[20] — currently have an EFB with airplane spotter. If airlines do not demand MVAs in the FMS, avionics manufacturers will not add them. But in the next generation of avionics, manufacturers could build their data models and display technology so that MVAs are there for the crew."

When MVAs are designed into the FMS, there is the potential for more intelligent information so warnings could be issued to the pilot when the airplane descends below an MVA. The industry only has begun to look at possible applications for MVA data, however, and the process of testing conversions of RVM MVA-chart data has just begun in 2004.

"This is all brand new — Jeppesen, for example, probably would begin to ingest all of FAA's data files, convert them into Jeppesen-standard format and decide how to provide them to avionics manufacturers," Terpstra said. "It will be at least a year before we announce to avionics manufacturers that the MVA data would be available. Typically, for a change like this, we would send sample files and the date of data availability to all avionics manufacturers in time for them to evaluate future effects on their systems.

"Airlines currently have higher-priority issues than this, however, such as duplicate/multiple identifier codes in approach procedures, RF legs [radius-around-a-fix approach segments; i.e., curved approaches for RNAV operation that are similar to DME arcs but do not require DME] and RNP [required navigation performance] values in the navigation database."

Jeppesen provides navigational-database updates that conform to ARINC 424 and provides other data in the Jeppesen-standard format to provide a specification change, new information, ARINC 424 revisions or internal Jeppesen policy changes.

**All classes of EFBs could have the ability to integrate electronic MVA charts in the near future.**

Providing electronic MVA charts to pilots as in-flight advisory information could involve the following methods:

- Electronic MVA charts — such as those produced from the paper MVA charts that non-U.S. civil aviation authorities have issued for pilot use — currently can be displayed for preflight briefings and in-flight advisory information. They have the same limitations as paper MVA charts, however;
- Electronic MVA charts with ownship position, which in the near future would provide functions similar to current Class 3 (permanently installed) EFB applications that already show the airplane spotter on an electronic airport diagram. As of September 2004, Jeppesen had not delivered a service that depicts MVAs with an airplane spotter;
- Moving-map display in a stand-alone GPS navigation system, which theoretically could show the aircraft position on a scalable chart and which currently can alert pilots before the aircraft enters various classes of airspace at specified altitudes; and,
- Next-generation FMS, a long-term solution that theoretically could alert pilots — with or without display of an electronic MVA chart — before the aircraft enters an MVA sector below the corresponding MVA.

The complexity of implementing electronic MVA charts in these and other methods is related to the underlying technologies. Current-generation EFBs and chart-display systems are designed to display precomposed images (i.e., the digital display exactly reproduces the paper chart); FMS, next-generation EFBs and stand-alone GPS navigation systems use data-driven information, dynamically generating graphic elements on the display from in-flight computations and stored data. Software that manipulates precomposed images can be implemented relatively quickly, but does not provide the required intelligence to generate automatic advisories.

"FMS technology does very well drawing routes as lines between VORs, waypoints, outer markers and various fixes, but typically not so well drawing pictures — such as the series of graphic elements that comprise an MVA chart — as graphical elements on a display," Terpstra said. "A substantial effort would be needed to modify today's FMSs to display graphical elements such as boundaries of MVA sectors."

All classes of EFBs could have the ability to integrate electronic MVA charts in the near future.

"EFB applications can draw a graphic such as an electronic chart on the display and put a moving airplane on top of it," he said. "That will be the first method of providing electronic MVA charts to pilots. If the EFB application uses current electronic charts, for example, georeferencing combined with position data from a GPS receiver, enables the application to generate an airplane spotter and see the airplane moving around on the approach chart or IFR area chart."

EFBs that combine a scalable MVA chart with an airplane spotter would enable pilots to see immediately where they are with respect to MVA sectors during radar vectoring, he said.

"The pilot then will be able to see altitudes and interpret the situation, but there will have to be mental processing by the pilot to warn about a problem — there would be no intelligence in the avionics to generate alerts," he said. "In contrast, with the intelligence of data-driven avionics and the required alphanumeric database, the system would provide a visual warning and/or aural warning if the aircraft began to go below the MVA."

System intelligence also automatically could turn on or turn off display of the electronic MVA chart based on aircraft position, altitude and flight path. Under SAE standards approved in August 2004 for the electronic display of aeronautical chart information, avionics manufacturers and chart producers will consider three criticality levels: Level 1, in which displayed information cannot be deselected/replaced by the pilot; Level 2, in which displayed information appears but can be deselected/replaced; and Level 3, in which information normally is not displayed but can be selected for display. Electronic MVA charts likely would be treated as Level 2 information or Level 3 information, Terpstra said.

"Technology out there right now enables display of the airplane spotter on top of non-U.S. MVA charts that already are within applications on aircraft that are certified to operate with them," Terpstra said. "Certification of all charts and georeferencing allow the use of these precomposed charts — including the non-U.S. MVA charts — with an airplane spotter. About 158 JeppView/FliteDeck electronic charts contain radar-vectoring altitudes (some are radar-vectored departure procedures), including about 125 that are freestanding MVA charts; these represent every one known to have been published in a state aeronautical information publication.

> **"Technology out there right now enables display of the airplane spotter on top of non-U.S. MVA charts."**

"If operators have FliteDeck or the current release of JeppView [the first generation of JeppView was delivered without the airplane-spotter capability], pilots already are able to see the aircraft position on top of any electronic MVA charts — or similar charts — in the world. There probably is not a lot of operator/pilot awareness yet, however, because of the limited number of systems in use."

Jeppesen issues updated electronic navigation charts every 14 days; these updates incorporate the most current information that may be issued by government sources, regardless of their revision cycles.

"Compared with issuing navigation charts, providing updated electronic MVA charts should be a fairly low-volume activity," Terpstra said. JeppView contains no charts that depict MIAs.

## MVA-data Applications May Complement TAWS

Bateman said that the ATC facilities developing MVA charts in the United States must comply with FAA standards while ensuring safe, orderly and efficient traffic flow — which inherently requires keeping as much controlled airspace as possible available around terminals.

"I sympathize if, in some cases, ATC facilities have difficulty complying with FAA standards for minimum altitudes and radar vectoring because of traffic growth and where the airport is sited, for example," he said. "Sometimes, if the ATC facility were to raise an MVA, they would lose airspace."

In the past, avionics engineers had wanted to consider MVA data for use in GPWS and for use later in EGPWS, he said.

"Back in the 1970s, I had found that MVA charts were not kept current, were not available in a public document and were not in a usable format for air carrier use," Bateman said. "So technology bypassed the possibility of using MVA data for terrain warnings. Looking back, I do not understand why it has taken 35 years — a period when all MVA data should have been publicly available and the industry could have developed new safety tools — for FAA to release MVA-chart data. I was very skeptical that public release of U.S. MVA data would become a reality in 2004. When we can get the MVA data, we will use it."

The original GPWS had an incompatibility between radar vectoring and the

GPWS system itself, he said. The reason was that the technical standard order for GPWS required certain performance, while ATC had separate standards for radar vectoring.

"I wrote letters to FAA beginning in 1975 but later I gave up," he said. "We then designed EGPWS to prevent unwanted terrain warnings within certain limits, to be compatible with ATC radar vectors and to give pilots more time to conduct an escape maneuver. Only under certain conditions could we eliminate those warnings, however. These include when we have very good aircraft-position data, integrity of terrain data and vertical accuracies. We also do not rely only on barometric altimetry; we rely on data from geometric altimetry (incorporating satellite-derived altitude data, radio-altitude data and high-quality terrain data)."

With current software, unwanted terrain warnings during radar vectoring virtually have been eliminated, he said. If a terrain warning or other anomaly occurs during radar vectoring, however, the aircraft operator always should investigate the reason — including the remote possibility that altitude data used by ATC were incorrect, said Bateman.

"If the investigation shows that the problem requires a change in the aircraft system, so be it; if the problem requires changing the MVA chart, so be it," he said. "After 10 years of experience with this technology, we feel good about being independent of ATC radar. If a controller operational error occurs today during radar vectoring, the risk of CFIT in an EGPWS-equipped aircraft is not as high as it used to be."

His company envisions various methods of introducing electronic MVA charts for advisory purposes into navigation systems such as the FMS or EFB.

"The natural place to put MVA data would be in the FMS database because these data are updated once a month," Bateman said.

Questions remain about when electronic MVA charts should be seen — if at all — and when they should be out of the pilot's sight.

"I envision applications that normally would *not* show MVAs because the MVAs could add visual clutter," he said. "If the pilot wants to see MVAs, we could enable that. Pilots probably would not want the MVA displayed very often during flight — 99 percent of all ATC clearances are proper and safe. Alternatively, if the airplane altitude or projected airplane altitude is below MVA, we could begin to show the MVA — not necessarily an MVA chart on a moving-map display — but perhaps on an attitude display. I would leave the question of any aural alert or visual alert to cockpit designers," Bateman said.

Incorporating crew-alerting intelligence into the FMS also might reduce the crew effort.

"We could make obvious the terrain hazard and the required action, perhaps with a change of MVA-sector color and perhaps by flashing twice the altitude number," Bateman said. "With this method, the crew would not see the electronic MVA chart very often, yet we would not disable a warning when needed. If an EFB were used as the platform, a moving-map display could incorporate a projected flight plan that similarly could flash an alert if something were wrong with the aircraft altitude relative to MVA."

Accuracy of navigation databases and terrain/obstacle databases is a constant concern, and manufacturers must be extremely careful how they achieve compatibility of terrain-warnings with radar-vectoring at MVA, he said.

"EGPWS, for example, functions without unwanted terrain warnings during radar vectoring until the aircraft descends to about 900 feet above ground level," Bateman said. "As far as we know, despite incompatibility with minimum altitudes used in FAA's air traffic control handbook, EGPWS will provide a timely terrain warning if something goes wrong during radar vectoring. Moreover, if the flight crew is operating at night or in instrument meteorological conditions, one pilot should have the EGPWS display on and the second display should show radar weather. Most, but not all, airlines have implemented this procedure. By establishing this procedure, pilots see that something is wrong on the terrain display before the terrain warning."

For terrain warnings during radar vectoring, such as before entering an area of higher terrain, an up-to-date database is critical, he said.

"Free worldwide database updates are available to all operators, and they virtually eliminate the problem of unwanted terrain warnings during radar vectoring," he said. "We recommend that operators twice a year download and install the current EGPWS database from the Internet, typically during an aircraft-maintenance A check or during a form of an A check."

Although no regulatory requirements exist for these database updates, if an accident occurs, operators can assume that failure to carry the current database will become an issue. Nevertheless, some operators in the United States and other countries operate with the database that was installed originally.

To continue improving safety during radar vectoring, every unwanted terrain warning in the airplane should be reported. "We want to know about every one," Bateman said. Similarly, air traffic controllers should report all unwanted alerts from minimum-safe-altitude warning systems (MSAW)[21] to the appropriate civil aviation authority for investigation and corrective action, he said. ■

## Notes

1. For example, the U.S. Federal Aviation Administration (FAA) *Aeronautical Information Manual* (*AIM*), 5-2-6C2, said in part, "ATC may assume responsibility for obstacle clearance by vectoring the [departing] aircraft prior to minimum vectoring altitude [MVA] by using a diverse vector area (DVA). The DVA has been assessed for departures that do not follow a specific ground track. ATC may also vector an aircraft off a previously assigned DP [departure procedure]. In all cases, the 200-feet-per-nautical-mile climb gradient is assumed and obstacle clearance is not provided by ATC until the controller begins to provide navigational guidance in the form of radar vectors." U.K. Civil Aviation Authority Civil Aeronautical Publication (CAP) 493, *Manual of Air Traffic Services* Part 1, similarly restricts radar controllers from instructing aircraft to descend below altitudes depicted on a radar-vectoring chart before the aircraft has intercepted the final approach track of a published instrument approach, except under a site-specific approval and for limited purposes. FAA Order 7110.65P, *Air Traffic Control*, Section 5-6-3, "Vectors Below Minimum Altitude," Aug. 5, 2004, said, "Except in en route automated environments in areas where more than 3.0 miles [4.8 kilometers] separation minima is required, you may vector a departing IFR aircraft, or one executing a missed approach, within 40 nautical miles [64 kilometers] of the antenna and before it reaches the minimum altitude for IFR operations if separation from prominent obstructions shown on the radar scope is applied in accordance with the following: a. If the flight path is 3.0 miles or more from the obstruction and the aircraft is climbing to an altitude at least 1,000 feet above the obstruction, vector the aircraft to maintain at least 3.0 miles separation from the obstruction until the aircraft reports leaving an altitude above the obstruction. b. If the flight path is less than 3.0 miles from the obstruction, and the aircraft is climbing to an altitude at least 1,000 feet above the obstruction, vector the aircraft to increase lateral separation from the obstruction until the 3.0-mile minimum is achieved or until the aircraft reports leaving an altitude above the obstruction. c. At those locations where [DVAs] have been established, terminal radar facilities may vector aircraft below the MVA/MIA within those areas and along those routes described in facility directives."

2. The International Civil Aviation Organization (ICAO) defines an aeronautical information publication (AIP) as "issued by or with the authority of a state and containing aeronautical information of a lasting character essential to air navigation."

3. Vandel, Robert H. "Flight Safety Foundation Approach-and-landing Accident Reduction Task Force: Air Traffic Control Training and Procedures/ Airport Facilities Working Group: Final Report (Version 1.2)." 1997. In "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 and Volume 18 (November 1998–February 1999).

4. Bateman, Don. Telephone interview by Rosenkrans, Wayne. Alexandria, Virginia, U.S. Aug. 16, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S.

5. Terpstra, James. Telephone interview by Rosenkrans, Wayne. Alexandria, Virginia, U.S. Aug. 27, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S. Jeppesen is a subsidiary of Boeing Commercial Aviation Services, a unit of Boeing Commercial Airplanes.

6. Directorate of Airspace Policy, U.K. Civil Aviation Authority (CAA). *Radar Vectoring Areas in U.K. Airspace: Policy and Design Criteria.* Civil Aeronautical Publication (CAP) 709, June 18, 2004.

7. U.S. Federal Aviation Administration (FAA). "Pilot–Controller Glossary," *Aeronautical Information Manual* (AIM). Feb. 19, 2004.

8. Cooper, Martyn. E-mail communication with Rosenkrans, Wayne. Alexandria, Virginia, U.S. Aug. 19, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S. Cooper is a London airport operational controller on loan as a desk officer from U.K. National Air Traffic Services to the Directorate of Airspace Policy – Terminal Airspace of the U.K. CAA. He also has been executive vice president professional of the International Federation of Air Traffic Controller Associations (IFATCA) and director professional of the U.K. Guild of Air Traffic Control Officers.

9. FAA has defined electronic flight bag (EFB) as follows in Advisory Circular 120-76A, *Guidelines for the Certification, Airworthiness and Operational Approval of Electronic Flight Bag Computing Devices:* "[An EFB is] an electronic display system intended primarily for cockpit/flight deck [use] or cabin use. EFB devices can display a variety of aviation data or perform basic calculations (e.g., performance data, fuel calculations, etc.). In the past, some of these functions were traditionally accomplished using paper references or were based on data provided to the flight crew by an airline's 'flight dispatch' function. The scope of the EFB system functionality may also include various other hosted databases and applications. Physical EFB displays may use various technologies, formats and forms of communication. These devices sometimes are referred to as auxiliary performance computers (APC) or laptop auxiliary performance computers (LAPC)."

   The AC also said, "Type A EFB software applications include precomposed, fixed presentations of data currently presented in paper format. [Precomposed information (is) previously composed into a static composed state (non-interactive). The composed displays have consistent, defined and verifiable content, and formats that are fixed in composition.] … Type B EFB [software] applications include dynamic, interactive applications that can manipulate data and presentation. … Pending [FAA Aircraft Evaluation Group (AEG)] human factors evaluation, panning, scrolling, zooming, rotating or other active manipulation is permissible for Type B applications. Electronic navigation charts should provide a level of information integrity equivalent to paper charts. … If an EFB is being used to display flight critical information such as navigation, terrain and obstacle warnings that require immediate action, takeoff and landing V-speeds, or for functions other than situational awareness, then such information needs to be in the pilot's primary field of view. … In addition, consideration should be given to the potential for confusion that could result from presentation of relative directions (e.g., positions of other aircraft on traffic displays) when the EFB is positioned in an orientation inconsistent with that information."

10. FAA. Order 7210.3T, *Facility Operation and Administration.* Feb. 19, 2004.

11. Lamond, Robert. Telephone interview by Rosenkrans, Wayne. Alexandria, Virginia, U.S. Aug. 16, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S.

12. U.S. Federal Aviation Regulations (FARs) Part 91.175, "Takeoff and Landing Under IFR," says in part, "Operations on unpublished routes and use of radar in instrument approach procedures. When radar is approved at certain locations for ATC purposes, it may be used not only for surveillance [radar approaches] and precision radar approaches, as applicable, but also may be used in conjunction with instrument approach procedures predicated on other types of radio navigational aids. Radar vectors may be authorized to provide course guidance through the segments of an approach to the final course or fix. When operating on an unpublished route or while being radar vectored, the pilot, when an approach clearance is received, shall, in addition to complying with Section 91.177, maintain the last altitude assigned to that pilot until the aircraft is established on a segment of a published route or instrument approach procedure unless a different altitude is assigned by ATC. After the aircraft is so established, published procedures apply to descent within each succeeding route or approach segment unless a different altitude is assigned by ATC. Upon reaching the final approach course or fix, the pilot may either complete the instrument approach in accordance with a procedure approved for the facility or continue a surveillance [radar approach] or precision radar approach to a landing."

13. FARs Part 91.177, "Minimum Altitudes for IFR Operations," says in part, "(a) Operation of aircraft at minimum altitudes. Except when necessary for takeoff or landing, no person may operate an aircraft under IFR below — (1) The applicable minimum altitudes prescribed in Parts 95 [*IFR Altitudes*] and 97 [*Standard Instrument Approach Procedures*] of this chapter; or (2) If no applicable minimum altitude is prescribed in those parts — (i) In the case of operations over an area designated as a mountainous area in Part 95, an altitude of 2,000 feet above the highest obstacle within a horizontal distance of 4.0 nautical miles [7.4 kilometers] from the course to be flown; or (ii) In any other case, an altitude of 1,000 feet above the highest obstacle within a horizontal distance of 4.0 nautical miles from the course to be flown."

14. Roberts, Wally. Telephone interview by Rosenkrans, Wayne. Alexandria, Virginia, U.S. Aug. 26, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S. Roberts is a retired TWA captain, an aviation writer and a volunteer consultant to the U.S. National Business Aviation Association (NBAA). He is a former chairman of the committee on terminal procedures for the Air Line Pilots Association, International.

15. Bergner, Steve. Telephone interview by Rosenkrans, Wayne. Alexandria, Virginia, U.S. Aug. 18, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S.

16. Swancy, Howard. Interview by Rosenkrans, Wayne. Washington, D.C., U.S. Sept. 9, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S.

17. The U.S. Government/Industry Charting Forum (ACF) is a biannual public meeting to discuss informational content and design of aeronautical charts and related products, as well as instrument flight procedures policy and criteria. The forum comprises the ACF Instrument Procedures Group and the ACF Charting Group.

18. Laydon, Terry. Interview by Rosenkrans, Wayne. Alexandria, Virginia, U.S. Aug. 30, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S. Requests for these data are processed by Fred Milburn, master staff cartographer, program and production management staff, FAA National Aeronautical Charting Office.

19. Hammett, Bill; Schneider, Tom. E-mail communication with Rosenkrans, Wayne. Washington, D.C. Aug. 31, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S. Hammett is a senior operations standards specialist for Innovative Solutions International (a contractor for FAA), and recording secretary of ACF. Schneider is an FAA terminal instrument procedures specialist, co-chairman of ACF and chairman of the ACF Instrument Procedures Group.

20. Kleiboer, Edwin. Telephone interview by Rosenkrans, Wayne. Alexandria, Virginia, U.S. Aug. 31, 2004. Kleiboer is project manager, electronic flight bag (EFB), for KLM Royal Dutch Airlines. He said that KLM received airworthiness certification of a taxiing application on Boeing Jeppesen Class 3 EFBs to be installed on 10 new Boeing 777-200ER airplanes from FAA and the European Joint Aviation Authorities (JAA) in September 2003. KLM took delivery of the first aircraft in October 2003. Three primary EFB software applications — a moving-map display of aircraft position (airplane spotter) on electronic airport diagrams, electronic airplane-performance computation and digital video surveillance of the cabin — were the first to be used in line operations, Kleiboer said. "The EFB will enable use of electronic charts for approach and departure, but we have not decided yet whether to implement KLM electronic charts or third-party electronic charts in the short term," he said. "We currently use our own paper navigation charts. The EFB can display MVA sectors. No additional certification will be required because Type A EFB applications [such as chart display] and Type B applications [such as interactive moving maps] can be added by obtaining operational approval from the national civil aviation authority."

21. The FAA *AIM* defines a minimum safe-altitude warning (MSAW) as "a function of the ARTS III computer that aids the controller by alerting him/her when a tracked mode-C-equipped aircraft is below or is predicted by the computer to go below a predetermined minimum safe altitude."

**Appendix A**
**Examples of Minimum Vectoring Altitude Information Available to Pilots by Country**

| ICAO Airport Code | Airport Name | City | Country | Jeppesen JeppView Electronic Chart Type | Revision Date |
|---|---|---|---|---|---|
| EBLG | Bierset Airport | Bierset | Belgium | Minimum Radar Vectoring Altitudes | 7/25/03 |
| EBBR | Brussels International Airport | Brussels | Belgium | Radar Vectoring Area | 5/21/99 |
| LQSA | Sarajevo International Airport | Sarajevo | Bosnia and Herzegovina | Radar Vectoring | 3/21/03 |
| LQTZ | Tuzla International Airport | Tuzla | Bosnia and Herzegovina | Radar Vectoring | 8/23/02 |
| FBSK | Sir Seretse Khana International Airport | Gaborone | Botswana | Minimum Radar Vectoring Altitudes | 9/23/94 |
| SCFA | Cerro Moreno Airport | Antofagasta | Chile | Minimum Vectoring Altitude Chart | 6/6/03 |
| SCDA | Diego Aracena Airport | Iquique | Chile | IFR Minimum Vectoring Altitude Clearance | 12/19/03 |
| SCEL | Santiago International Arturo Merino Benítez Airport | Santiago | Chile | Minimum Vector Altitude Clearance | 12/19/03 |
| SCTE | El Tepual Airport | Puerto Montt | Chile | IFR Minimum Altitude Vector Clearance | 9/12/03 |
| SCCI | Carlos Ibañez del Campo International Airport | Punta Arenas | Chile | IFR Minimum Vector Altitude Clearance | 9/12/03 |
| SKBO | El Dorado International Airport | Santafe de Bogotá | Colombia | Minimum Vectoring Altitudes | 11/22/02 |
| MROC | Juan Santamaría International Airport | San José | Costa Rica | IFR Minimum Vectoring Altitudes Clearance | 12/5/03 |
| LKTB | Brno Turany Airport | Brno | Czech Republic | Minimum Radar Vectoring Altitudes | 10/4/02 |
| LKMT | Ostrava Airport | Mosnov | Czech Republic | Minimum Radar Vectoring Altitudes | 10/4/02 |
| LKVO | Vodochody Airport | Prague | Czech Republic | Minimum Radar Vectoring Altitudes | 10/4/02 |
| LKPR | Ruzyne Airport | Prague | Czech Republic | Minimum Radar Vectoring Altitudes | 7/11/03 |
| LKKV | Karlovy Airport | Vary | Czech Republic | Minimum Radar Vectoring Altitudes | 10/4/02 |
| SEQU | Mariscal Sucre International Airport | Quito | Ecuador | IFR Minimum Vector Altitude Clearance | 10/10/03 |
| HECA | Cairo International Airport | Cairo | Egypt | Radar Vectoring | 12/20/02 |
| HEGN | Hurghada Airport | Hurghada | Egypt | Radar Vectoring | 12/20/02 |
| HELX | Luxor International Airport | Luxor | Egypt | Radar Vectoring | 12/20/02 |
| HESH | Sharm el Sheikh Airport | Sharm el Sheikh | Egypt | Radar Vectoring | 12/20/02 |
| LFCI | Albi Airport | Albi | France | Minimum Radar Vectoring Altitudes | 10/4/02 |
| LFBZ | Biarritz Anglet Bayonne Airport | Anglet | France | Radar Vectoring | 8/9/02 |
| LFLP | Annecy Haute Savoie Airport | Annecy | France | Radar Vectoring Chart | 3/12/04 |
| LFMV | Caumont Airport | Avignon | France | Radar Vectoring | 12/20/02 |
| LFOA | Avord Airport | Avord | France | Radar Vectoring | 12/20/02 |

**Appendix A**
**Examples of Minimum Vectoring Altitude Information Available to Pilots by Country (continued)**

| ICAO Airport Code | Airport Name | City | Country | Jeppesen JeppView Electronic Chart Type | Revision Date |
|---|---|---|---|---|---|
| LFKB | Bastia Airport | Bastia | France | Radar Vectoring | 8/9/02 |
| LFBE | Bergerac Airport | Bergerac | France | Radar Vectoring | 8/9/02 |
| LFAC | Calais Dunkerque Airport | Calais | France | Radar Vectoring | 8/16/02 |
| LFQT | Merville Airport | Calonne | France | Radar Vectoring | 8/16/02 |
| LFMD | Cannes Airport | Cannes | France | Radar Vectoring | 4/18/03 |
| LFMK | Carcassonne Salvaza Airport | Carcassonne | France | Minimum Radar Vectoring Altitudes | 10/4/02 |
| LFRK | Caen Airport | Carpiquet | France | Minimum Radar Vectoring Altitudes | 10/4/02 |
| LFCK | Mazamet Airport | Castres | France | Minimum Radar Vectoring Altitudes | 10/4/02 |
| LFBC | Cazaux Airport | Cazaux | France | Radar Vectoring | 12/20/02 |
| LFRC | Cherbourg Maupertus Airport | Cherbourg | France | Minimum Radar Vectoring Altitudes | 10/4/02 |
| LFBG | Cognac Airport | Cognac | France | Radar Vectoring | 8/9/02 |
| LFSD | Darois Airport | Dijon | France | Minimum Radar Vectoring Altitudes | 10/4/02 |
| LFKF | Figari Sud Corse Airport | Figari | France | Radar Vectoring | 12/20/02 |
| LFLS | Grenoble-St. Geoirs Airport | Grenoble | France | Radar Vectoring | 3/12/04 |
| LFTH | Toulon Airport | Hyeres | France | Radar Vectoring | 8/23/02 |
| LFMI | Istres Airport | Istres | France | Radar Vectoring | 12/20/02 |
| LFOH | Le Havre-Octeville Airport | Le Havre | France | Minimum Radar Vectoring Altitudes | 10/4/02 |
| LFLY | Bron Airport | Lyon | France | Radar Vectoring | 3/12/04 |
| LFOB | Beauvais Airport | Paris | France | Radar Vectoring | 12/20/02 |
| LFPT | Cormeilles-en-Vexin Airport | Pontoise | France | Radar Vectoring | 12/20/02 |
| LFRG | Deauville Airport | St.-Gatien-des-Bois | France | Minimum Radar Vectoring Altitudes | 10/4/02 |
| LFOT | Val de Loir Airport | Tours | France | Radar Vectoring | 12/20/02 |
| LFQB | Troyes Airport | Troyes | France | Radar Vectoring Chart | 8/2/02 |
| LFLV | Vichy Airport | Vichy | France | Radar Vectoring | 12/20/02 |
| EDDB | Schonefeld Airport | Berlin | Germany | Radar Vectoring Area | 2/13/04 |
| EDDI | Tempelhof Airport | Berlin | Germany | Radar Vectoring Area | 2/13/04 |
| EDDT | Tegel Airport | Berlin | Germany | Radar Vectoring Area | 2/13/04 |
| EDDF | Frankfurt International Airport | Frankfurt | Germany | Minimum Radar Vectoring Altitudes | 2/6/04 |
| LGAV | Athens International Airport | Athens | Greece | Radar Vectoring Area | 1/31/03 |
| LGKR | Kerkira Airport | Corfu | Greece | Radar Vectoring | 8/15/03 |
| LGRP | Rhodes International Airport | Rhodes | Greece | Radar Vectoring Area | 1/31/03 |
| LGTS | Makedonia Airport | Thessaloniki | Greece | Radar Vectoring Area | 2/7/03 |

**Appendix A**
**Examples of Minimum Vectoring Altitude Information Available to Pilots by Country** (continued)

| ICAO Airport Code | Airport Name | City | Country | Jeppesen JeppView Electronic Chart Type | Revision Date |
|---|---|---|---|---|---|
| VABB | Jawaharlal Nehru International Airport | Bombay | India | Radar Vectoring | 8/22/03 |
| WAAA | Hasanuddin Airport | Mandai-Maros | Indonesia | Minimum Vector Altitude Clearance | 8/27/99 |
| WIIJ | Adisutjipto Airport | Yogyakarta | Indonesia | Minimum Vector Altitude Clearance | 6/18/99 |
| OIII | Mehrabad International Airport | Tehran | Iran | Radar Vectoring | 12/20/02 |
| LLBG | David Ben Gurion International Airport | Tel Aviv | Israel | Radar Vector Departure Runways 26 and 30 | 8/22/03 |
| LIMC | Malpensa Airport | Malpensa | Italy | Radar Vectoring Area | 9/17/99 |
| LIML | Linate Airport | Milan | Italy | Radar Vectoring Area | 9/17/99 |
| LIRF | Fiumicino Airport | Rome | Italy | Radar Vectoring Area | 9/17/99 |
| LIMF | Turin International Airport | Turin | Italy | Radar Vectoring Area | 2/4/00 |
| OJAM | Amman-Marka International Airport | Amman | Jordan | Minimum Vectoring Altitudes | 10/4/02 |
| WBKK | Kota Kinabalu International Airport | Kota Kinabalu | Malaysia | Radar Vectoring Arrival/ Departure | 10/10/97 |
| WMSA | Sultan Abdul Aziz Shah Airport | Kuala Lumpur | Malaysia | Minimum Vectoring Altitudes | 11/22/02 |
| WBGG | Kuching International Airport | Kuching | Malaysia | Radar Vectoring Arrival/ Departure | 10/10/97 |
| WBGR | Miri Airport | Miri | Malaysia | Radar Vectoring Area | 8/15/03 |
| MMAA | Gen. Juan N. Alvarez International Airport | Acapulco | Mexico | Minimum Vector Altitude Clearance | 1/16/04 |
| MMUN | Cancún International Airport | Cancún | Mexico | IFR Minimum Vectoring Altitudes | 2/27/04 |
| MMCU | Gen. Roberto Fierro Villalobos International Airport | Chihuahua | Mexico | Minimum Vector Altitudes | 11/7/03 |
| MMGL | Guadalajara Miguel Hidalgo y Costilla International Airport | Guadalajara | Mexico | IFR Minimum Vectoring Altitudes | 1/30/04 |
| MMHO | Hermosillo Airport | Hermosillo | Mexico | Minimum Vector Altitude | 10/10/03 |
| MMMX | Benito Juárez International Airport | Mexico City | Mexico | Minimum Vector Altitudes | 1/3/03 |
| MMMY | Gen. Mariano Escobedo International Airport | Monterrey | Mexico | IFR Minimum Vector Altitude Clearance | 12/6/02 |
| MMPR | Gustavo Díaz Ordaz Airport | Puerto Vallarta | Mexico | IFR Minimum Vectoring Altitudes | 1/16/04 |
| MMTJ | Gen. Abelardo L. Rodríguez International Airport | Tijuana | Mexico | IFR Minimum Vector Altitude Clearance | 12/6/02 |
| OOMS | Seeb International Airport | Muscat | Oman | Radar Vectoring Area | 1/30/04 |
| MPTO | Tocumen Airport | Panama City | Panama | Minimum Vectoring Altitudes | 2/14/03 |
| RPVM | Mactan International Airport | Cebu City | Philippines | Minimum Vector Altitude Chart | 6/20/03 |
| RPLL | Ninoy Aquino International Airport | Manila | Philippines | Minimum Vector Altitude Clearance | 8/1/03 |
| RPLB | Subic Bay International Airport | Subic Bay | Philippines | Minimum Vector Altitude Chart | 2/28/03 |
| EPGD | Trojmiasto Airport | Gdansk | Poland | Minimum Radar Vectoring Altitudes | 3/28/03 |
| EPWA | Frederic Chopin Airport | Warsaw | Poland | Radar Vectoring | 4/4/03 |
| LPBJ | Beja Airport | Beja | Portugal | Radar Vectoring | 8/23/02 |

**Appendix A**
**Examples of Minimum Vectoring Altitude Information Available to Pilots by Country** (continued)

| ICAO Airport Code | Airport Name | City | Country | Jeppesen JeppView Electronic Chart Type | Revision Date |
|---|---|---|---|---|---|
| LPLA | Lajes Acores Airport | Lajes Acores | Portugal | Minimum Radar Vectoring Altitudes | 7/11/03 |
| LPPR | Francisco Sa Carneiro Airport | Maia | Portugal | Radar Vectoring | 8/23/02 |
| USCC | Chelyabinsk–Balandino Airport | Chelyabinsk | Russia | Radar Vectoring Arrivals Runway 09 | 1/30/04 |
| USCC | Chelyabinsk–Balandino Airport | Chelyabinsk | Russia | Radar Vectoring Arrivals Runway 27 | 1/30/04 |
| URMM | Mineralnyye Vody Airport | Mineralnyye Vody | Russia | Radar Vectoring Arrivals Runway 12 From North | 3/12/04 |
| URMM | Mineralnyye Vody Airport | Mineralnyye Vody | Russia | Radar Vectoring Arrivals Runway 30 From North | 3/12/04 |
| URMM | Mineralnyye Vody Airport | Mineralnyye Vody | Russia | Radar Vectoring Arrivals Runway 12 From East, South and West | 3/12/04 |
| URMM | Mineralnyye Vody Airport | Mineralnyye Vody | Russia | Radar Vectoring Arrivals Runway 30 From East, South and West | 3/12/04 |
| LJLJ | Ljubljana Airport | Ljubljana | Slovenia | Minimum Radar Vectoring Altitudes | 11/1/02 |
| LEAM | Almeria Airport | Almeria | Spain | Minimum Radar Vectoring Altitudes | 3/28/03 |
| LEMG | Málaga Airport | Málaga | Spain | Radar Vectoring | 7/19/02 |
| LEVC | Valencia Airport | Manises | Spain | Radar Vectoring Area | 7/12/02 |
| LEPA | Palma de Mallorca Airport | Palma de Mallorca | Spain | Radar Vectoring Area | 7/12/02 |
| LEST | Santiago Airport | Santiago de Compostela | Spain | Radar Vectoring Area | 7/12/02 |
| LEBB | Bilbao Airport | Sondika/Vizcaya | Spain | Minimum Radar Vectoring Altitudes | 7/11/03 |
| RCYU | Hualien Airport | Hualien | Taiwan, China | Minimum Vectoring Altitudes | 6/19/98 |
| RCLG | Taichung Airport | Taichung | Taiwan, China | Minimum Vectoring Altitudes | 10/10/97 |
| DTMB | Habib Bourguiba International Airport | Monastir | Tunisia | Radar Vectoring | 1/24/03 |
| DTTA | Tunis–Carthage International Airport | Tunis | Tunisia | Radar Vectoring Area | 1/24/03 |
| LTAC | Ankara Esenboga Airport | Ankara | Turkey | Minimum Radar Vectoring Altitudes | 9/10/99 |
| LTAI | Antalya International Airport | Antalya | Turkey | Minimum Radar Vectoring Altitudes | 5/17/02 |
| LTFE | Bodrum–Milas Airport | Bodrum | Turkey | Minimum Radar Vectoring Altitudes | 1/30/04 |
| LTBS | Dalaman International Airport | Mugla | Turkey | Minimum Radar Vectoring Altitudes | 11/12/99 |
| LTBA | Istanbul Ataturk Airport | Istanbul | Turkey | Minimum Radar Vectoring Altitudes | 5/17/02 |
| LTBL | Izmir–Cigli Airport | Izmir–Cigli | Turkey | Minimum Radar Vectoring Altitudes | 3/10/00 |

**Appendix A**
**Examples of Minimum Vectoring Altitude Information Available to Pilots by Country (continued)**

| ICAO Airport Code | Airport Name | City | Country | Jeppesen JeppView Electronic Chart Type | Revision Date |
|---|---|---|---|---|---|
| UKLR | Rovno Airport | Rovno | Ukraine | Radar Vectoring Arrival Procedures Runways 12 and 30 | 7/25/03 |
| EGPD | Aberdeen Airport | Aberdeen | United Kingdom | Radar Vectoring Area | 9/19/03 |
| EGNS | Isle of Man Airport | Ballasalla | United Kingdom | Radar Vectoring Area | 9/6/02 |
| EGAA | Belfast International Airport | Belfast | United Kingdom | Radar Vectoring Area | 5/9/03 |
| EGKB | London Biggin Hill Airport | Biggin Hill | United Kingdom | Radar Vectoring Area | 8/1/03 |
| EGBB | Birmingham International Airport | Birmingham | United Kingdom | Radar Vectoring Area | 12/8/00 |
| EGNH | Blackpool Airport | Blackpool | United Kingdom | Radar Vectoring Area | 9/19/03 |
| EGGD | Bristol International Airport | Bristol/Bath | United Kingdom | Radar Vectoring Area | 9/26/03 |
| EGTG | Bristol Filton Aerodrome | Bristol | United Kingdom | Radar Vectoring Area | 11/29/02 |
| EGSC | Cambridge City Airport | Cambridge | United Kingdom | Radar Vectoring Area | 1/16/04 |
| EGFF | Cardiff International Airport | Cardiff | United Kingdom | Radar Vectoring Area | 1/30/04 |
| EGHH | Bournemouth Airport | Christchurch | United Kingdom | Radar Vectoring Area | 3/26/04 |
| EGBE | Coventry Airport | Coventry | United Kingdom | Radar Vectoring Area | 6/7/02 |
| EGNV | Teesside International Airport | Darlington | United Kingdom | Radar Vectoring Area | 1/16/04 |
| EGPH | Edinburgh Airport | Edinburgh | United Kingdom | Radar Vectoring Area | 6/8/01 |
| EGTE | Exeter International Airport | Exeter | United Kingdom | Radar Vectoring Area | 1/30/04 |
| EGPF | Glasgow Airport | Glasgow | United Kingdom | Radar Vectoring Area | 7/25/03 |
| EGPK | Glasgow Prestwick International Airport | Glasgow | United Kingdom | Radar Vectoring Area Runways 13, 21 and 31 | 10/17/03 |
| EGJB | Guernsey Airport | Guernsey | United Kingdom | Radar Vectoring Area | 3/8/02 |
| EGNR | Hawarden Airport | Hawarden | United Kingdom | Radar Vectoring Area | 3/19/04 |
| EGJJ | Jersey Airport | Jersey | United Kingdom | Radar Vectoring Area | 3/19/99 |
| EGNJ | Humberside International Airport | Kirmington | United Kingdom | Radar Vectoring Area | 12/19/03 |
| EGNM | Leeds Bradford International Airport | Leeds | United Kingdom | Radar Vectoring Area | 1/16/04 |

**Appendix A**
**Examples of Minimum Vectoring Altitude Information Available to Pilots by Country (continued)**

| ICAO Airport Code | Airport Name | City | Country | Jeppesen JeppView Electronic Chart Type | Revision Date |
|---|---|---|---|---|---|
| EGPB | Sumburgh Airport | Lerwik | United Kingdom | Radar Vectoring Area | 10/3/03 |
| EGGP | Liverpool John Lennon Airport | Liverpool | United Kingdom | Radar Vectoring Area | 4/11/03 |
| EGLF | Farnborough Airport | London | United Kingdom | Radar Vectoring Area | 12/20/02 |
| EGGW | London Luton Airport | London | United Kingdom | Radar Vectoring Area | 4/18/03 |
| EGKK | London Gatwick Airport | London | United Kingdom | Radar Vectoring Area | 7/19/02 |
| EGLC | London City Airport | London | United Kingdom | Radar Vectoring Chart | 2/13/04 |
| EGLL | Heathrow Airport | London | United Kingdom | Radar Vectoring Chart | 8/1/03 |
| EGSS | London Stansted Airport | London | United Kingdom | Radar Vectoring Area | 3/29/02 |
| EGCC | Manchester Airport | Manchester | United Kingdom | Radar Vectoring Area | 7/11/03 |
| EGCD | Manchester Woodford Airport | Manchester | United Kingdom | Radar Vectoring Area | 4/4/03 |
| EGMH | London Manston Airport | Manston | United Kingdom | Radar Vectoring Area | 11/28/03 |
| EGNT | Newcastle International Airport | Newcastle upon Tyne | United Kingdom | Radar Vectoring Area | 8/29/03 |
| EGNX | East Midlands Airport | Nottingham | United Kingdom | Radar Vectoring Area | 2/20/04 |
| EGPM | Scatsa Airport | Shetland Island | United Kingdom | Radar Vectoring Area | 4/28/00 |
| EGHI | Southampton International Airport | Southampton | United Kingdom | Radar Vectoring Area | 6/8/01 |
| EGMC | London Southend Airport | Southend-on-Sea | United Kingdom | Radar Vectoring Area | 12/19/03 |
| EGBJ | Staverton Airport | Staverton | United Kingdom | Radar Vectoring Area | 10/31/03 |
| EGAC | Belfast City Airport | Sydenham-By-Pass | United Kingdom | Radar Vectoring Area | 11/28/03 |
| EGHG | Yeovil Airport | Yeovil | United Kingdom | Radar Vectoring Area | 8/23/02 |
| SUMU | Carrasco International Airport | Montevideo | Uruguay | IFR Minimum Vector Altitudes Clearance | 12/5/03 |

ICAO = International Civil Aviation Organization

Note: Paper charts are published by the respective civil aviation authorities and also are available to pilots in paper form and electronic form. The table comprises various types that provide minimum vectoring altitudes (MVAs, or similarly defined altitudes) in the Jeppesen JeppView library of electronic charts for flight operations under instrument flight rules. In addition to charts listed, IFR terminal-area charts in some countries also contain information about altitudes that may be assigned by air traffic controllers.

Source: James Terpstra (with FSF research to identify airport name, city and country)

# Approach-and-landing Accident Severity Decreases in 2003 for Large Commercial Jets

**Although approach-and-landing accidents (ALAs) continued to be the largest accident category for the worldwide commercial jet fleet, ALAs produced a smaller percentage of total fatalities and a smaller percentage of total hull-loss accidents than in 2002.**

— FSF EDITORIAL STAFF

Western-built, large commercial jet airplanes[1] were involved in 32 accidents worldwide in 2003 (Table 1, page 30), an increase of two compared with 2002. The majority — 20 accidents (63 percent) — were approach-and-landing accidents (ALAs).[2] That was a higher percentage of ALAs than the 57 percent in 2002.

Nevertheless, ALAs accounted for smaller percentages of total fatalities and of total hull losses than in the previous year. In 2003, ALAs were responsible for 121 fatalities, or 25 percent of the year's total 483 fatalities, compared with 36 percent in 2002. ALAs resulted in seven hull losses[3] in 2003 (58 percent of the 12 hull losses), compared with 10 of the 14 hull losses (71 percent) in 2002.

The data were compiled by The Boeing Co. in its annual statistical summary of accident data.[4]

The 483 fatalities in 2003 (482 onboard) compared with 702 (558 onboard) in 2002.

For the 10-year period 1994 through 2003, loss of control in flight resulted in the greatest number of fatalities (2,238, including 103 in 2003; Figure 1, page 31).

*Continued on page 31*

**ALAs accounted for smaller percentages of total fatalities and of total hull losses than in the previous year.**

**Table 1**
**Airplane Accidents, Worldwide Commercial Jet Fleet, 2003**

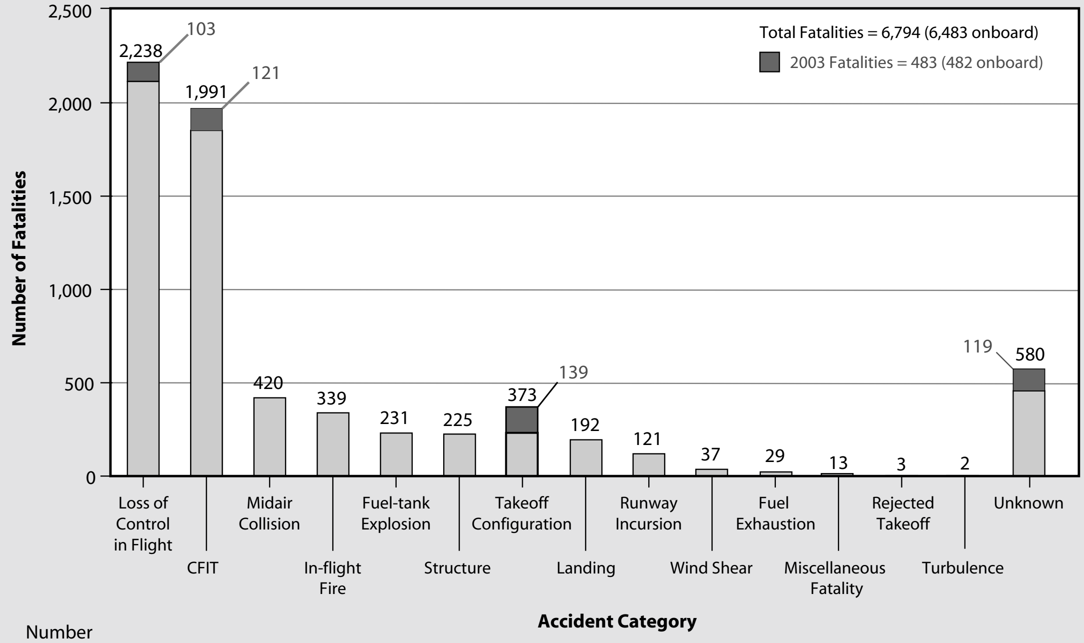
| Date | Airline | Airplane Type | Accident Location | Hull Loss | Fatalities | Phase of Flight | Description |
|---|---|---|---|---|---|---|---|
| Jan. 8, 2003 | Turkish Airlines | Canadair RJ100 | Diyarbakir, Turkey | X | 75 | Final approach | CFIT, struck mountain |
| Jan. 8, 2003 | TAN Airlines | Fokker F28 | Chachapoyas, Peru | X | 46 | Initial approach | CFIT, struck mountain |
| Jan. 17, 2003 | TAME | Fokker F28 | Quito, Ecuador | | 0 | Takeoff | Rejected takeoff/runway excursion |
| Jan. 23, 2003 | Star Air | Boeing 737-200 | Jakarta, Indonesia | | 0 | Landing | Runway excursion |
| Jan. 26, 2003 | VASP Airlines | Boeing 737-200 | Rio Branco, Brazil | X | 0 | Initial approach | Struck tree on approach to land |
| Feb. 15, 2003 | Evergreen International Airlines | Boeing 747-200 | Catania, Italy | | 0 | Landing | Runway overrun on landing |
| March 7, 2003 | Air Algerie | Boeing 737-200 | Tamanrasset, Algeria | X | 103 | Takeoff | Struck terrain after takeoff |
| March 12, 2003 | Singapore Airlines | Boeing 747-400 | Auckland, New Zealand | | 0 | Takeoff | Tail strike on takeoff |
| March 21, 2003 | Royal Air Maroc | Boeing 737-400 | Marrakech, Morocco | | 0 | Landing | Landing overrun |
| March 21, 2003 | Transasia Airways | Airbus A321 | Tainan, Taiwan, China | | 0 | Landing | Runway excursion |
| March 26, 2003 | Royal Air Maroc | Boeing 737-400 | Oujda, Morocco | | 0 | Landing | Runway excursion |
| March 31, 2003 | AirTran Airways | Boeing 717-200 | New York, New York, U.S. | | 0 | Parked | Evacuation injuries |
| April 18, 2003 | Wetrafa Airlift | McDonnell Douglas DC-9-32 | Brazzaville, Congo | X | 0 | Landing | Intentional off-runway gear-up landing |
| June 17, 2003 | Onur Air | McDonnell Douglas MD-88 | Groningen, Netherlands | | 0 | Takeoff | Rejected takeoff overrun |
| July 6, 2003 | Cielos del Peru | McDonnell Douglas DC-10-30 | Curitiba, Brazil | | 0 | Landing | Landing overrun |
| July 8, 2003 | Sudan Airways | Boeing 737-200 | Port Sudan, Sudan | X | 116 | Initial climb | Struck terrain after takeoff |
| July 11, 2003 | Air Memphis | Boeing 707-300C | Dacca, Bangladesh | X | 0 | Takeoff | Rejected takeoff overrun |
| Aug. 11, 2003 | Garuda Indonesia | Fokker F28 | Jakarta, Indonesia | | 0 | Landing | Left-main landing gear collapse |
| Aug. 15, 2003 | EasyJet | Boeing 737-300 | Geneva, Switzerland | | 0 | Climb | Hail damage in flight |
| Sept. 12, 2003 | Northwest Airlines | McDonnell Douglas DC-9-15 | Norfolk, Virginia, U.S. | | 1 | Tow | Tractor driver killed |
| Oct. 1, 2003 | Cargo Air Lines | Boeing 747-200C | Liege, Belgium | | 0 | Landing | Landing overrun |
| Oct. 3, 2003 | Garuda Indonesia | Boeing 737-500 | Semarang, Indonesia | | 0 | Landing | Runway departure |
| Nov. 1, 2003 | EgyptAir | Airbus A321-230 | Moscow, Russia | | 0 | Taxi | Skidded off runway |
| Nov. 6, 2003 | TAME | Airbus A320 | Florianopolis, Brazil | | 0 | Landing | Runway offside excursion |
| Nov. 29, 2003 | Hydro Air | Boeing 747-258C | La Guaira, Venezuela | | 0 | Landing | Runway offside excursion |
| Dec. 7, 2003 | East African Safari Air | Fokker F28 | Lokichokio, Kenya | X | 0 | Landing | Runway excursion |
| Dec. 13, 2003 | Aero Continente | Boeing 737-200 | Lima, Peru | | 0 | Landing | Landed with all landing gear retracted |
| Dec. 18, 2003 | FedEx | McDonnell Douglas MD-10-10 | Memphis, Tennessee, U.S. | X | 0 | Landing | Right-main landing gear collapse, fuselage burned |
| Dec. 18, 2003 | Líneas Aéreas Suramericanas | McDonnell Douglas DC-9-15F | Mitu, Colombia | X | 3 | Descent | Struck jungle terrain |
| Dec. 19, 2003 | Air Gabon | Boeing 737-300 | Libreville, Gabon | X | 0 | Landing | Landing overrun during heavy rain |
| Dec. 20, 2003 | GOL Transportes Aéreos | Boeing 737-700 | Navegantes, Brazil | | 0 | Landing | Landing overrun |
| Dec. 25, 2003 | Union Des Transports Africains | Boeing 727-200 | Cotonou, Benin | X | 139 | Takeoff | Struck building on takeoff |
| **32** | **Total** | | | **12** | **483** | | |

CFIT = Controlled flight into terrain

Source: The Boeing Co.

**Figure 1**

**Fatalities by Accident Category, Worldwide Commercial Jet Fleet, 1994–2003**




| Number of Fatal Accidents (105 Total) | 32 | 24 | 2 | 2 | 2 | 1 | 2 | 16 | 3 | 1 | 3 | 8 | 1 | 2 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

CFIT = Controlled flight into terrain

Note: Accidents involving multiple non-onboard fatalities are included. Accidents involving single, non-onboard fatalities are excluded. Fatalities/accidents are placed in one category only.

Source: The Boeing Co.

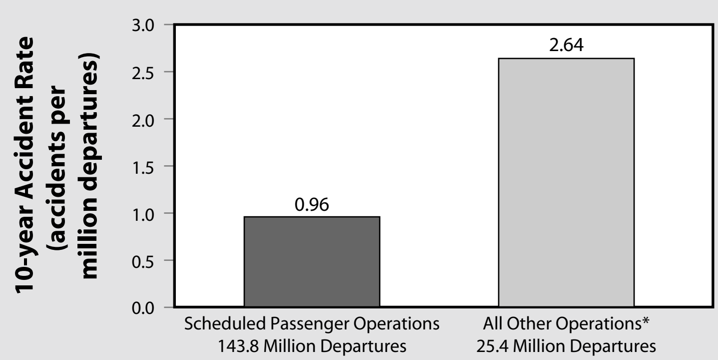
Controlled flight into terrain (CFIT)[5] was responsible for the second-greatest number of fatalities (1,991, including 121 in 2003).

The 1994–2003 rate for hull-loss accidents and/or fatal accidents was 0.96 per million departures for scheduled passenger operations and 2.64 per million departures for all other operations (Figure 2).

For the 10-year period, the combined final approach phase of flight and landing phase (beginning at the final approach fix) included more than half (51 percent) of the total accidents and 18 percent of the total fatalities (Figure 3, page 32). Including accidents during the initial approach (beginning at the

**Figure 2**

**Accident Rates by Type of Operation, Hull-loss Accidents and/or Fatal Accidents, Worldwide Commercial Jet Fleet, 1994–2003**

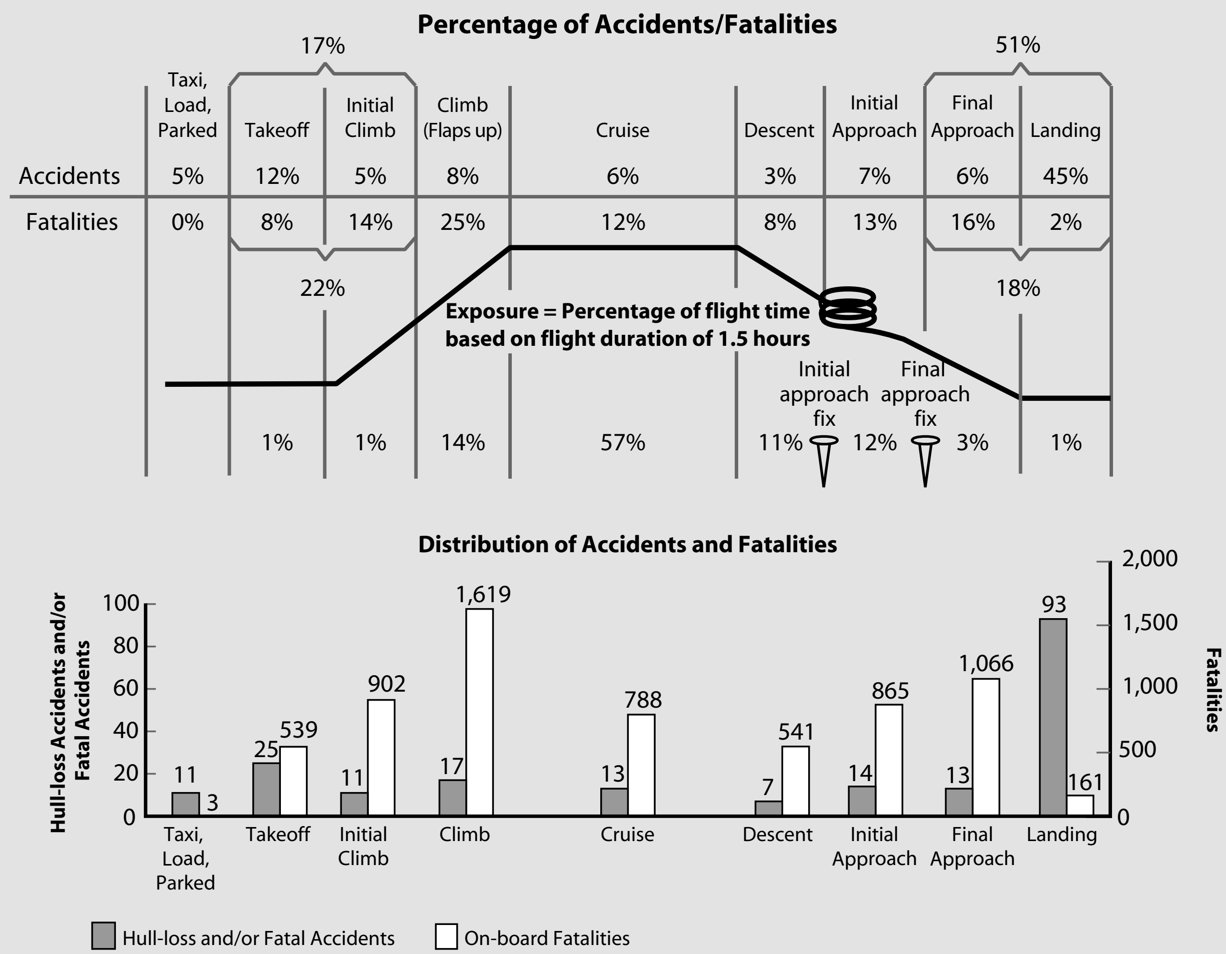



*Unscheduled passenger and charter, cargo, ferry, test, training and demonstration.

Source: The Boeing Co.

**Figure 3**

**Accidents and Onboard Fatalities by Phase of Flight, Hull-loss Accidents and/or Fatal Accidents, Worldwide Commercial Jet Fleet, 1994–2003**




Source: The Boeing Co.

initial approach fix) would add 7 percent to the accidents (i.e., 58 percent of the accidents were ALAs) and 13 percent to the fatalities (i.e., 31 percent of the fatalities were caused by ALAs). The combined takeoff phase and initial climb phase included 17 percent of accidents and 22 percent of fatalities during this period.

Landing was the phase of flight in which hull-loss accidents and/or fatal accidents occurred most often in 1994 through 2003 (Figure 3), including 93 accidents out of the total of 204 (46 percent). The largest number of fatalities occurred in accidents during the climb (1,619 fatalities out of a total of 6,484, or 25 percent).

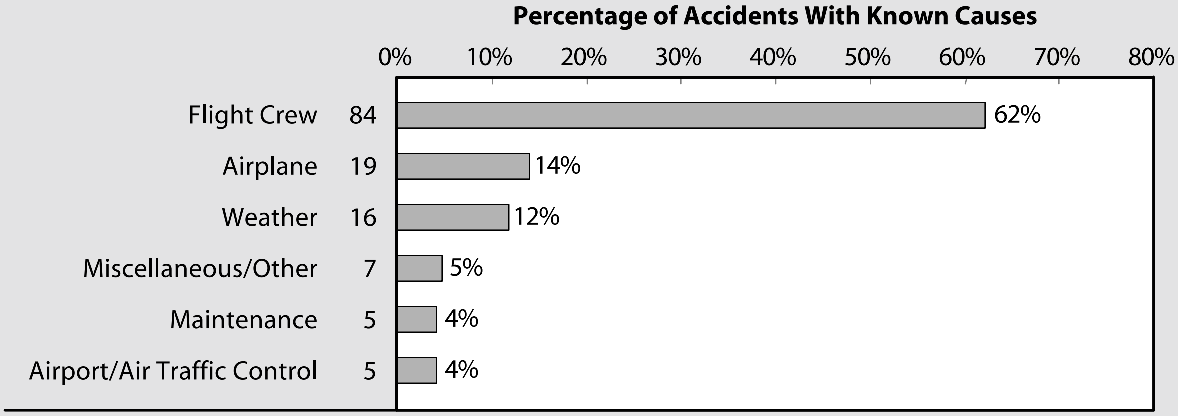
For the 1994–2003 period, the primary-cause category (as determined by investigative authorities) cited the flight crew in 62 percent of hull-loss accidents with known causes (Figure 4, page 33). The airplane and weather were primary-cause categories in 14 percent and 12 percent of hull-loss accidents, respectively.

One fatal accident in 2003 involved a lead agent–driver who died of injuries sustained when the towbar became disconnected from the aircraft during pushback, and the tractor struck the aircraft on Sept. 12, 2003, at Norfolk, Virginia, U.S.

Excluded from the 2003 accident data, because it resulted from "hostile action," was an Airbus A300 cargo aircraft that was struck by a ground-launched missile at Baghdad, Iraq, on Nov. 22, 2003. Although the airplane's hydraulic systems became inoperable, the flight crew was able to maneuver and land the airplane. There were no injuries. ■

**Figure 4**

**Accidents by Primary Cause,[1]
Hull-loss Accidents and/or Fatal Accidents, Worldwide Commercial Jet Fleet,
1994–2003**




| | |
|---|---|
| Total With Known Causes | 136 |
| Unknown or Awaiting Reports | 50 |
| Total | 186 |

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

Source: The Boeing Co.

## Notes

1. The data included commercial jet airplanes with maximum gross weights of more than 60,000 pounds (27,000 kilograms). Airplanes manufactured in the Soviet Union or the Commonwealth of Independent States were excluded because of inadequate operational data. Commercial airplanes in military service were excluded.

2. Approach-and-landing accidents (ALAs) were those that Boeing classified as occurring in the initial approach, final approach or landing phases of flight.

3. *Hull loss* was defined as airplane damage that is substantial and is beyond economic repair. The term also included events in which the airplane was missing or was substantially damaged and inaccessible.

4. Boeing has revised the data shown in Figure 1 since publication of its summary. This article uses the revised data. Sachs, Andrew W., safe data manager, in-service safety and airworthiness, The Boeing Co. E-mail communication with Darby, Rick. Alexandria, Virginia, U.S. Sept. 9, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S.

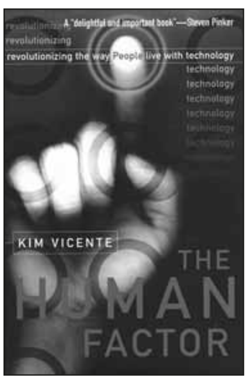
5. Controlled flight into terrain (CFIT) occurs when an airworthy aircraft under the control of the flight crew is flown unintentionally into terrain, obstacles or water, usually with no prior awareness by the crew. This type of accident can occur during most phases of flight, but CFIT is more common during the approach-and-landing phase, which begins when an airworthy aircraft under the control of the flight crew descends below 5,000 feet above ground level (AGL) with the intention to conduct an approach and ends when the landing is complete or the flight crew flies the aircraft above 5,000 feet AGL en route to another airport.

STATS

# Crew Resource Management Is Called a 'Human-tech' Success Story

**Advanced technology, says *The Human Factor*, is often poorly designed for the people who work with it. The author finds that, although aviation has its man vs. machine conflicts, the industry has made progress in taming them.**

— FSF LIBRARY STAFF




## Books

***The Human Factor: Revolutionizing the Way People Live With Technology.*** Vicente, Kim. New York, New York, U.S.: Routledge, 2004. 352 pp. Figures, index.

"More and more, we're being asked to live with technology that is technically reliable, because it was created to fit our knowledge of the physical world, but that is so complex or so counterintuitive that it's actually unusable by most human beings," says the author, an engineer specializing in human factors. The computer program that generates incomprehensible error messages, or audio-video equipment that requires complicated inputs using tiny buttons on a remote unit, are frustrating but not dangerous. In air carrier operations and corporate aviation, however, where many flight tasks are automated but require human programming, a poor "fit" between the way human pilots think and act and the technology they control can have very serious consequences.

The book discusses the problem of designing human-centered technology in many fields — including medical care, nuclear power plants and automobiles — and has a number of observations about how the interaction between users and aviation technology can be smooth or awkward.

Some flight deck–automation design problems are more subtle than the frequently discussed issues of data entry to the flight-management system and interpretation of "glass-cockpit" displays. For example, the author says, "The problem of crew coordination is actually made more complex in the latest cockpits, with their new array of controls for computer automation (and not just because there are now only two crewmembers instead of three). Old-style cockpits had analog meters, knobs, switches and other types of controls spread out all over the cockpit panels. As a result, the physical movements of one crewmember were a visible indication of what he was doing: if you saw your fellow crewmember leaning to the right and putting his hand on a certain switch, you knew he was probably raising the landing gear, but if he was looking upward at an analog meter, you knew he was probably checking on the status of the electrical systems. …

"The arrival of computer technology in the modern cockpit changed all that — inadvertently. Now, almost all the information is presented on computer monitors, and thanks to the marvels of automation, pilots can bring up displays for checking on the hydraulics, displays for looking at the weather, and so on; it's all at their fingertips — they just have to choose which display to look at. … Because physical movement is curtailed, pilots don't receive as much information from the actions of their partners. Most of the time, they're just sitting and staring at the computer screens, regardless of what they're thinking about or working on. So there isn't as much 'free information' as there used to be; each crewmember has to explicitly communicate his or her intent and actions by talking to the other, if they're to keep in tune with each other. That takes a lot more effort and concentration than a glance out of the corner of your eye."

The author gives the aviation industry much credit for solving, or working around, difficulties in human-technology interaction. He describes crew resource management (CRM) as a "human-tech success story," and believes that voluntary, nonpunitive reporting systems have alerted crews and technology designers to unintended consequences of modern flight-management systems.

Organizations, as well as misapplied technology, can create unintentional problems by ignoring the "human factor," the author says.

"Often, corporate priorities are muddy or counterproductive — people who are meant to be working together instead may unknowingly pull in different directions, or even worse, actively compete against each other," he says. "Also, responsibilities are not explicit, or if they are, they may contain structural conflicts of interest … . And even if all of those difficulties are dealt with, the right information still doesn't get to the right people at the right time; the communication patterns required to get the job done effectively haven't been built into the team or organization.

"Even with the right information, individuals may not have the required expertise to interpret that information and use it to make effective decisions. Sometimes, people don't know what they don't know, so it's up to the 'system designers' of the corporation to determine what skills are necessary for each job and to ensure that all employees have the requisite skill set."

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***Aviation Maintenance Management.*** Kinnison, Harry A. New York, New York, U.S.: McGraw-Hill, 2004. 299 pp. Figures, tables, appendixes, glossary, index.

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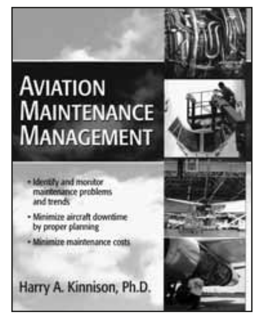
The author, an instructor in aviation maintenance management at Embry-Riddle Aeronautical University, Daytona Beach, Florida, U.S., says that he wrote this book because no suitable text for his courses existed. It is organized into five parts: fundamentals of maintenance, technical services, maintenance and materiel support, oversight functions and appendixes.

"We will be looking at the 'big picture,'" the author says in the introduction. "We will be looking at maintenance, engineering and management as an integrated whole. We will examine how these disciplines combine and coordinate to accomplish the goals and objectives of airline maintenance."

The book is intended for those who have a background and experience in aviation maintenance and a wish to move into management positions in an airline's maintenance and engineering operations. Managers who do not have a technical background in maintenance also will benefit from the book, the author says.

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***The Cambridge Aerospace Dictionary.***
Gunston, Bill (ed.). Cambridge, England: Cambridge University Press, 2004. 750 pp. Appendixes.

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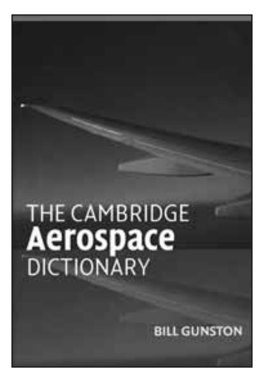
From A (general symbol for area, aspect ratio, amperes, et al.) to Zytel (trade name for nylon materials that remain flexible at cryogenic cold temperatures), the book includes technical terminology for the aerospace industry and for specific aircraft.

This edition is based on three previous editions of *Jane's Aerospace Dictionary* and includes 15,000 new terms, mostly acronyms. The editor says in the introduction, "There is little point in saying again that acronyms are an infectious disease, especially in the world of aerospace. [While] admitting that the incentive to abbreviate is often strong, it is self-defeating if the reader has a choice of more than 20 interpretations and does not know which one to pick." ATDC, for example, stands for Assisted Target Detection and Classification, Automatic Target Detection and Classification, and Automated Target Detection and Classification.

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***Teaming Up: Components of Safety Under High Risk.*** Dietrich, Rainer; Jochum, Kateri (eds.). Aldershot, England: Ashgate Publishing, 2004. 135 pp. Figures, index.

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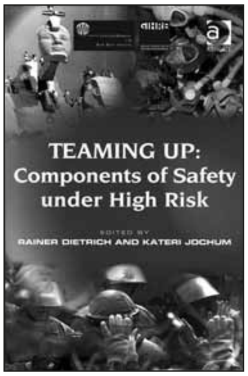


The book consists of presentations on the theme of teamwork as it relates to risk in the workplace, from the Gottlieb Daimler and Karl Benz Foundation's colloquium, "Interaction in High Risk Environments." Chapter 6, by Judith Orasanu, Ute Fischer and Jeannie Davison, concerns "Risk Perception and Risk Management in Aviation."

"In this paper, we focus on 'plan continuations,' a pattern common to many aviation accidents, and discuss how pilots' risk assessment and risk management strategies may play a role in this type of event," the authors say. "Plan continuation" is a term coined by the U.S. National Transportation Safety Board for decision errors in which a flight crew maintained its original plan, even though the conditions on which the plan was based had changed.

Research for the paper addressed the following questions:

- How do pilots think about flight risk?
- What risks are of greatest concern to them?
- How do risk factors influence decision difficulty? and,
- How do pilots typically manage risk?

The authors researched pilots' concepts of risk through a survey of pilots from a major U.S. air carrier. A second study presented pilots from a major U.S. air carrier with hypothetical scenarios in which decision making was complicated by ambiguous conditions. The pilots were asked to choose between continuing with an original plan that posed a threat to flight safety, but which if successful would entail economic, professional, productivity and social gains, and a change of plan that would increase the safety margin but would incur economic losses or other losses.

The authors say, "Situations that involve a conflict between different types of risk, especially those that pit safety against economic considerations, were reported by pilots to increase the difficulty of decisions. How they settle these kinds of decision dilemmas was found to depend on their assessment of the safety risk. If they judged the safety threat to be 'close to or beyond their comfort zone,' they adopted a plan that would assure safety but might incur economic [losses] or productivity losses. On the other hand, if they judged the safety risk to be less serious, they modified their current plan to mitigate threats to flight safety while satisfying their company's economic [goals] and productivity goals.

"These findings attest to the inherent subjectivity of risk assessment, especially in situations that are characterized by ambiguous [conditions] and dynamically changing conditions. Moreover, these findings suggest that faulty risk assessment rather than inappropriate action decisions may be a dominant factor in plan-continuation errors."

## Reports

***The Effects of NEXRAD Graphical Data Resolution and Direct Weather Viewing on Pilots' Judgments of Weather Severity and Their Willingness to Continue a Flight.*** Beringer, D.B.; Ball, J.D. U.S. Federal Aviation Administration (FAA) Office of Aerospace Medicine (OAM). DOT/FAA/AM-04/5. March 2004. 14 pp. Figures, color images, appendix, references. Available on the Internet at <http: //www.cami.jccbi.gov > or through NTIS.*

"The difference between making decisions in visual meteorological conditions and [making decisions] in instrument meteorological conditions is not trivial," says the report. With regard to weather conditions, decision making is influenced by location of storm cells, location of precipitation and convective activity. Pilots use visual observation of weather conditions and electronic instrumentation that displays data on weather, navigation (terrain, obstacles and routes) and traffic to determine if changes in the flight path are needed and when those changes should occur. One example of weather instrumentation is the next-generation radar (NEXRAD), which shows radar displays in graphic form and geographic weather locations.

Some in the aviation community are concerned that high-resolution radar images encourage pilots to use the data for tactical navigation by observing the location of precipitation or convective activity relative to aircraft position but to ignore the dynamic nature of weather and the limitations of reflective radar. To test the validity of this concern, a study was designed to determine how changes in resolutions of displayed NEXRAD data can affect data interpretation and pilot decision making.

This report is based on a study of 32 pilots to assess how variations in resolution of displayed NEXRAD graphical data are interpreted when a pilot has a direct (out-the-window) view of weather. Four levels of resolution were tested. The lowest display resolution showed a broad field of images, and higher resolution permitted imagery of finer detail in a focused area. During the study, observations were made as pilots performed simulator flights and responded to weather scenarios at various display resolutions. Assessments of their responses were evaluated by observers and participants using the following criteria:

- Visual-performance data (how long pilots accessed the data);
- Flight-performance data (how close they came to the significant weather);
- Length of time pilots deferred their decisions about continuing the flights; and,
- Pilots' responses to equivalent weather data presented at differing resolutions in the non-flight environment.

Pilots appeared to spend more time looking at higher-resolution images than at lower-resolution images, thus deferring longer their decisions. The report says that this reinforces the idea that "higher-resolution images are likely to encourage pilots to continue flights with the expectation that they can fly around or between significant weather features. The presence of out-the-window viewable weather phenomena was seen to have a significant effect on how pilots regarded the NEXRAD data."

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***Light Utility Helicopter Safety in Australia.*** Australian Transport Safety Bureau (ATSB). Aviation Research Paper BE04/73. June 2004. 44 pp. Figures, tables, appendix. Available on the Internet at <http://www.atsb.gov.au/aviation/research/index.cfm> or from ATSB.**

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Light utility helicopters (LUHs) made up half the fleet of registered helicopters in Australia, yet were involved in 72 percent of helicopter accidents between January 1985 and December 2003, according to a 2003 study of safety trends for the previous 20 years.

During that period, LUHs played an increasing role in Australian civil aviation. The number of LUH aircraft tripled, the total number of flying hours doubled and the number of LUH aircraft increased to represent half of the Australian helicopter fleet. These aircraft perform flying activities with various risk profiles, such as aerial mustering (controlling the movement of livestock), flight training, agricultural operations, personal transport and business transport.

This report compares the relative safety of four types of LUHs that were similar in usage and similar in design — including the number of engines and reciprocating engine or turbine engine — to determine if any particular model experienced a higher risk than similar aircraft. Tables of comparative data by manufacturer and by helicopter model show numbers of accidents (fatal and nonfatal), accident rates per registered aircraft, accident rates per hours flown, type of operation in which the accident occurred and accident outcomes.

Some of the report's conclusions are the following:

- The overall safety trend for LUHs in number of accidents and accident rate per hours flown has improved since 1990;
- The number of accidents, the accident rate per flying hours, and the accident rate per registered aircraft decreased from 1990 to 2002;
- LUH operations with the lowest accident rates per hour flown are flight training, charter operations and other aerial work;
- Most LUH accidents involved collisions with terrain or other obstacles, such as trees or power lines; and,
- "Aircraft handling" or maintenance, repair, design and construction factors contributed to the majority of accidents.

***Effect of Helicopter Rotors on GPS Reception.*** U.K. Civil Aviation Authority (CAA). CAA Paper 2003/07. December 2003. 65 pp. Figures, tables, appendix, references, glossary. Available on the Internet at <www.caa.co.uk> or from Documedia.***

Suitable installation locations for global positioning system (GPS) antennas on helicopters are limited by the shape of the airframe. It is not always possible to ensure that the line-of-sight signal path to GPS satellites will be clear of the regions swept by the helicopter's rotor blades. The report describes a series of experiments, performed on behalf of the U.K. Civil Aviation Authority (CAA), that investigated the effect of turning rotor blades on the reception of GPS signals.

The test aircraft was a Sikorsky S-76C, which was operated in a series of ground runs during which the rotational speed of the rotors was varied. The effects of the operation on three dissimilar GPS receivers were monitored.

Among the study's conclusions were the following:

- "The helicopter rotors were demonstrated to introduce a periodic modulation onto the [coarse/acquisition] code GPS satellite signals;
- "Rotor 'interference' was identified with the GPS antenna mounted in two different positions (adjacent to the tail rotor and underneath the main rotor) … . The nature of the modulation was observed to differ in the two cases;
- "The effect of the rotor modulation upon the carrier-to-noise ratio of the received signals was estimated to be between –3 dB [decibels] and –8 dB;
- "No evidence was obtained for the rotor 'interference' having affected the range-measurement accuracy of a GPS receiver; [and,]
- "Considerable caution must be applied when interpreting signal-level figures generated by a GPS receiver in the presence of rotor 'interference.'"

## Regulatory Materials

***The Avoidance of Fatigue in Aircrews: Guide to Requirements.*** U.K. Civil Aviation Authority (CAA). Civil Aviation Publication (CAP) 371. Fourth edition. January 2004. 105 pp. Tables, appendixes. Available on the Internet at <www.caa.co.uk> or from Documedia.***

In the 1950s, it was recognized that a contributory factor in some aircraft accidents may have been flight crew fatigue, and efforts to regulate hours worked by flight crews began. Restrictions placed on the number of hours worked developed over time to ensure that crewmembers are sufficiently rested prior to commencing a duty period.

The first edition of CAP 371, issued in April 1975, established a standard for flight-time limitation and defined the basic framework for duty hours of flight crew and cabin crew. It reflected a balance among industry practices, aeromedical evidence and what was considered best for the common good of people in the United Kingdom.

The document contains mandatory requirements for the civil aviation flight time limitation (FTL) scheme and recommended guidelines. Sections define, in detail, responsibilities of operators and responsibilities of crewmembers. Appendixes contain four examples of FTL schemes that companies operating scheduled services, helicopters, air taxi, charters and others can adopt if desired. Guidance documents provide examples of staff roster preparation and a schedule matrix of days off.

The document includes Amendment 1, dated May 12, 2004. ■

### Sources

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

** Australian Transport Safety Bureau (ATSB)
P.O. Box 967
Civic Square, ACT 2608 Australia
Internet: <http://www.atsb.gov.au>

*** Documedia Solutions
37 Windsor St.
Cheltenham, Gloucester GL52 2DG U.K.
Internet: <http://www.documedia.co.uk>

# Leaking Fuel Tank in Boeing 777 Prompts Return to Airport

**The report by the U.K. Air Accidents Investigation Branch said that the purge door for the center fuel tank was not installed.**

— 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

## Another Crew Saw Smoke, Smelled Fuel Vapor From Incident Airplane

**Boeing 777. No damage. No injuries.**

Immediately after takeoff from an airport in England for a flight to Zimbabwe, the flight crew was told that the crew of an airplane at the runway holding point had observed smoke trailing the incident airplane and had smelled fuel. The flight crew observed no abnormal indications on flight instruments and decided that their airplane's center fuel tank probably was leaking.

The crew dumped fuel to reduce the airplane's weight to maximum landing weight and returned to the departure airport.

Aircraft rescue and fire fighting personnel inspected the airplane after the landing and said that there were no apparent fuel leaks but that vapor was emanating from the left-main landing-gear assembly. The engine was shut down and the airplane was taxied to the gate (stand) where passengers disembarked normally.

An inspection of the left-main landing-gear bay revealed that the center fuel tank's purge door was not installed but was instead "hanging on a lanyard inside the fuel tank," the preliminary report said. "A plastic bag was attached to the purge-door opening. The bag contained fuel, and it also contained the screws that would normally hold the purge door in place."

Before startup, the airplane's center fuel tank, which has a capacity of 98,800 liters (26,103 U.S. gallons) or 80,000 kilograms (176,368 pounds) of fuel, was slightly more than half full — the fuel level was slightly below the purge-door opening but high enough that the airplane's pitch attitude during climb-out would have allowed fuel to flow through the opening.

Records showed that a 2C maintenance check requiring work on the center fuel tank was performed between May 2 and May 4, 2004; there was no record of any subsequent work that would have required access to the center fuel tank or removal of the purge door. After the 2C check, the airplane was flown on 53 sectors before the incident flight; the most fuel in the center fuel tank on any of those sectors was 28,000 kilograms (61,729 pounds).

During the 2C check, leak checks were performed on all fuel-tank doors that had been removed for routine jobs; a leak check was not performed on the purge door. Some maintenance personnel told incident investigators that they were unaware of the purge door; the incident report said that the aircraft maintenance manual's information on the required minimum fuel quantities to check fuel-tank access doors for leaks did not mention the purge door. The manual's information on removal and reinstallation of the purge door said that the subsequent leak check should be conducted with a minimum of 32,000 kilograms (70,547 pounds) of fuel in the tank. The report said, however, that 32,000 kilograms of fuel was insufficient to reach the purge-door opening. (After the incident, the manufacturer revised the requirement to 52,163 kilograms [114,999 pounds] of fuel.)

Investigation of the incident also revealed that a rear spar inspection had been performed improperly, the report said.

Investigation of the purge-door incident is continuing.

## Pilot's Braking Technique Cited in Runway Excursion

**Boeing 737. Minor damage. No injuries.**

The airplane had been flown from Ireland to Belgium on the crew's third flight of the day.

The runway was wet from light drizzle. The report said that after touchdown, the speed brake was deployed, as usual, and the first officer (the pilot flying) selected reserve thrust. The crew said later that deceleration was normal. The captain took the controls before the airplane reached the runway exit, when the airplane was traveling about 80 knots.

The report said, "As the runway surface was wet, she [the captain] elected to continue towards the runway end … a distance of approximately 2,500 feet [763 meters] further on. At approximately 70 knots, reverse thrust was canceled, brakes were applied and [were] released. … Nearing the turnoff, … the captain reapplied the brakes and, in her words, 'they never reapplied.'"

Repeated application of the wheel brakes and heavy pressure on the brake pedals produced no braking effect. At 60 knots, the captain turned the airplane onto the exit using only the nosewheel tiller. The nosewheel and part of the right-main landing-gear wheel assembly rolled off the taxiway onto the grassy threshold area, where the crew shut down both engines. Passengers disembarked normally and were transported by bus to the terminal. The airplane was towed to the apron (ramp).

The report said that the manufacturer's recommended manual braking technique — smoothly applying constant brake-pedal pressure — was not used and that "several attempts at reducing the speed by modulating the brakes were unsuccessful, as the brake-pedal pressure was being released and efficiency [was being] lost."

The report cited the following as the cause of the accident: "The late use of an inappropriate braking technique that failed to achieve a safe taxi speed [and] led to the uncontrolled departure of the aircraft from the taxiway onto the grassy area."

## Cowling Separates From Airplane During Takeoff

**Airbus A320. Minor damage. No injuries.**

Visual meteorological conditions prevailed for the departure from an airport in the United States. Immediately after takeoff, a flight attendant told the captain that a passenger had reported observing "a cover come off the left engine."

Flight instruments did not indicate a problem, and the captain asked the flight attendant to look out the window; the flight attendant confirmed that part of the left engine cowling was missing. At the same time, the captain felt the airplane vibrate and told air traffic control that he planned to return the airplane to the departure airport. The no. 1 engine oil quantity indicator illuminated, and the captain declared an emergency. The crew landed the airplane without further incident.

A preliminary inspection revealed that both sides of the left engine cowling had separated from the airplane, that the left engine pylon had been bent and that the left wing slat outboard of the engine nacelle was dented and punctured. Authorities recovered the missing sections of the cowling, and the investigation was continuing.

AIR TAXI/COMMUTER

## AIRPROX Incident Prompts Recommendations on Use of Airspace

**Bombardier DHC-8 Dash 8. No damage. No injuries.**

The airplane was being flown through clouds in uncontrolled airspace over the North Sea when the flight crew was told by air traffic control (ATC) that two aircraft were approaching at high speed. The crew also received a resolution advisory (RA) from the airplane's traffic-alert and collision avoidance system (TCAS); the crew complied with the RA to climb. The TCAS message indicated that vertical separation between the aircraft was 100 feet.The pilot later reported the incident as an AIRPROX (aircraft proximity) incident. (The U.K. Civil Aviation Authority defines an AIRPROX as "a situation in which, in the opinion of a pilot or a controller, the distance between aircraft, as well as their relative positions and speed, have been such that the safety of the aircraft involved was, or may have been, compromised.")

An investigation revealed that the other aircraft involved in the incident were two BAE Systems Sea Harriers from a Royal Navy vessel in the North Sea. The Sea Harriers were being flown on an air defense exercise, and the pilots had been told to visually identify a radar target.

The incident report said, "Once the Sea Harrier pilots identified this [target] as a Dash 8 aircraft, they broke off the intercept to the southwest. The minimum separation recollected by the crews on the intercepting aircraft radar was 1.8 nautical miles [3.3 kilometers]."

A review of radar data from one radar facility indicated that the minimum separation distance had been 3,700 feet (1,129 meters); data from a second radar facility showed that the minimum separation distance had been 3,450 feet (1,052 meters).

After the incident, the U.K. Air Accidents Investigation Branch (AAIB) recommended that CAA re-examine airspace categorization, procedures and services available for civil transport aircraft operating in unregulated airspace; that the Ministry of Defence review military aircraft operations in the same areas; and that both the CAA and the Ministry of Defence review the concurrent use of the unregulated airspace "with the aim of eliminating airproxes and potential collisions, with likely large-scale loss of life, between civil air transport and military aircraft."

## Pilot Swerves Airplane to Avoid Striking Vehicle During Emergency Landing

**Cessna 208. Destroyed. Five serious injuries, one minor injury.**

The airplane was being flown on an early morning visual flight rules flight in Tanzania. The pilot said that the takeoff roll was normal, but when he began a left turn soon after the airplane became airborne, he heard a "buff" sound from the engine. Engine oil splashed onto the windshield, and the engine stopped.

After use of the emergency power lever (which controls fuel supply to the engine after a pneumatic system failure) did not restore power, the pilot feathered the propeller, conducted a passenger briefing and decided to land the airplane on a paved road. As he was preparing for touchdown, the pilot observed a slow-moving vehicle near his intended touchdown point and turned the airplane left to avoid a collision, causing airspeed to decrease. The airplane landed hard on the left side of the road and struck piles of stones.

A preliminary investigation did not determine the reason for the engine failure.

## Improper Fuel Management Cited in Accident During Emergency Landing

**Piper PA-23-250 Aztec. Destroyed. Six serious injuries.**

The airplane was being flown on a night charter flight in India when, about 30 minutes after takeoff, both engines stopped. The pilot attempted to conduct an emergency landing, but the airplane struck terrain.

The accident report said that the probable cause was depletion of fuel in the inboard fuel tanks "on account of improper fuel management, as fuel was available in outboard tanks and the pilot forgot to change over the fuel selection from inboard tanks to outboard tanks in time." The report said that the pilot forgot to switch fuel tanks because of "task-saturation in a time-critical situation." The report also cited "distraction, fatigue [and] lack of currency on type of aircraft."

A factor contributing to the accident was the pilot's "non-adherence to the recommended and approved procedures of the aircraft flight manual," the report said.

CORPORATE/BUSINESS

## Airplane Strikes Trees During GPS Approach in Instrument Conditions

**Piper PA-31T Cheyenne. Destroyed. Six fatalities.**

Instrument meteorological conditions prevailed and an instrument flight rules flight plan had been filed for the late morning business flight in Australia. The pilot had received air traffic control (ATC) clearance to fly the airplane direct to a global positioning system (GPS) initial approach fix for a GPS approach to the destination airport.

The pilot told ATC at 1045 that he was beginning the approach, and soon afterward, he broadcast on the airport's common traffic advisory frequency that he was conducting the approach. At 1103, the pilot had not reported landing the airplane at the airport; ATC declared a distress phase, and a search began. The wreckage was found later in the day on a tree-covered ridge about 34 kilometers (18 nautical miles) southeast of the airport.

Witnesses who had heard an airplane in the area just before the accident said that the engine sounds were normal and that the airplane sounded as though it was "very low." A preliminary investigation found that both engines had been producing power when the airplane struck trees, that the landing gear and flaps had been extended and that the airplane was in a wings-level, climbing attitude.

Recorded radar data showed that the airplane was being flown toward the initial approach fix on a track 3.83 degrees left of the direct track. One day earlier, the pilot had flown the same airplane along the same route with no indication of tracking anomalies.

## Airplane Strikes Terrain During Night IMC

**Piper PA-32R-301T Turbo Saratoga. Destroyed. Five fatalities.**

Night instrument meteorological conditions (IMC) prevailed and an instrument flight rules flight plan had been filed for the business flight in the United States.

The pilot and a pilot-rated passenger who was serving as a safety pilot had begun an instrument landing system (ILS) approach and had received instructions from air traffic control (ATC) that the airplane was "six [nautical] miles [11 kilometers] from the marker, turn heading 050, maintain 3,000 until established, cleared ILS 3 approach." One of the pilots replied "cleared for the approach," and seconds later, ATC said that radar services were terminated and that the pilots should use the airport advisory frequency; the pilots acknowledged the instructions, but no further transmissions from the airplane were heard.

The wreckage was found in a wooded area at 1,079 feet, about 0.5 nautical mile (0.9 kilometer) west of Runway 03, "approximately abeam the 500-foot [153-meter] markers painted on the runway surface," a report said. The wreckage was oriented on a 280-degree heading, and the main fuselage was on a 230-degree heading.

The altimeter reading was 2,340 feet, the altimeter setting was 29.88 inches of mercury, the vertical speed indicator showed a 500-feet-per-minute rate of climb, and the horizontal situational indicator was aligned to 275 degrees. The heading bug was set to 030 degrees.

Airport weather five minutes before the accident included winds from 310 degrees at three knots, visibility of 2.5 statute miles (4.0 kilometers) in mist, a few clouds at 200 feet above ground level (AGL) and an overcast layer at 1,800 AGL, a temperature of 64 degrees Fahrenheit (F; 18 degrees Celsius [C]), dew point of 62 degrees F (17 degrees C), and an altimeter setting of 29.86 inches of mercury.

Three minutes after the accident, visibility was 0.75 statute mile (1.2 kilometers) in mist, with scattered clouds at 200 feet AGL and 500 feet AGL and an overcast layer at 1,800 feet AGL.

Minimums for the straight-in approach were 0.75 statute mile visibility, with a minimum descent altitude of 1,421 feet (250 feet AGL).

The missed approach procedure called for a climb to 3,000 feet and flight direct to a very-high-frequency omnidirectional radio 6.7 nautical miles (12.4 kilometers) northeast of the airport.

## Flap Separates From Airplane During Approach

**Lockheed 1329-23E Jetstar. Minor damage. No injuries.**

Visual meteorological conditions prevailed and an instrument flight rules flight plan had been filed for the midday business flight in the United States.

On final approach at the destination airport, as the flaps were extended to the "full flaps" position, the airplane decelerated and rolled left.

The report said, "The pilot regained control of the airplane by accelerating to 165 [knots] to 170 knots and holding right roll control. The landing touchdown and roll was uneventful."

Crewmembers inspected the airplane, which had 13,500 flight hours and 11,500 flight cycles, and observed that the left-inboard flap had separated from the airplane, with the attach bolts still in the flap-attach brackets. A more detailed inspection of the failure point at the inboard-flap attaching point revealed marks and corrosion pitting on the castings. Further inspection was planned.



## Airplane Strikes Power Line After Partial Engine Failure

**Rockwell S-2R. Substantial damage. One minor injury.**

Visual meteorological conditions prevailed for the agricultural aerial application flight in the United States. The pilot said that, while applying pesticide, the engine blower malfunctioned, causing a partial reduction of power. As a result, he decided to fly the airplane to a nearby airport for landing.

As the pilot began to turn the airplane toward the airport, the airplane struck a power line. The airplane was equipped with a wire cutter, which cut the 0.5-inch (1.3-centimeter) power line. The pilot continued the flight to the nearby airport, where he conducted a landing.

## Airplane Strikes Wires During Approach to Field

**Socata Rallye 100ST. Minor damage. No injuries.**

The pilot conducted a departure from an airport in Ireland, intending to show his passenger an aerial view of their neighborhood and to land in a field nearby. Before the flight, the landowner gave permission for the landing and the pilot walked around the field to evaluate its suitability for landing. He observed two sets of power cables that were suspended from east to west across the northern end of the field.

Later, the pilot conducted a low-altitude flight over the field from south to north. As he leveled the airplane about 20 feet to 25 feet above ground level, he observed a set of power cables immediately ahead of the airplane.

"To avoid the cables, the pilot pitched the aircraft down," the report said. "The cables cleared the propeller and the canopy. However, immediately after this, the aircraft suddenly pitched nose up, followed by a sudden pitch-down movement."

The pilot flew the airplane away from the field without conducting a landing and returned to the departure airport. An inspection revealed wire damage to the leading edge of the vertical tail fin, the elevator and the very-high-frequency omnidirectional radio antenna. The pilot said that the accident resulted from his "failure to adequately survey the entire landing site on foot"; his difficulty in observing the cables, which were not visible because of their location within trees; and the visual impairment caused by the sun's position near the horizon.

## Airplane Flips Over on Downsloping Runway

**Luscombe 8A. Substantial damage. No injuries.**

The pilot was returning the airplane to Runway 27 at an airport in England after a flight in the area.

The grass runway is about 680 meters (2,231 feet) long, with a downward slope for the last 200 meters (656 feet). During the landing roll, the airplane bounced about four feet into the air; the pilot increased power to help control the rate of descent that followed the bounce, and with the added power, the airplane rolled onto the downsloping section of the runway. When the pilot applied the brakes, the airplane nosed over and stopped inverted.

The report said, "In a candid report from the pilot, he concluded that the accident had been caused by applying the brakes [while] going downhill."

ROTORCRAFT

## Helicopter Strikes Tree During Chase of Wildlife Poachers

**Bell 206L-3 LongRanger. Substantial damage. No injuries.**

Day visual meteorological conditions prevailed for the game-scouting flight being conducted in support of anti-poaching activities in a national park in Tanzania. After poachers were observed on hills within the park, authorities on the ground began pursuing them, and the helicopter was landed in a clearing to allow two other law enforcement personnel to disembark.

The pilot then conducted a takeoff, planning to fly the helicopter to its base to board more law enforcement personnel for the anti-poaching activities.

The accident report said, "In haste to get altitude for the return flight to the base, [the pilot] did not notice that there was a branch of a tree over the main rotor."

As the pilot initiated a climb, he heard a "rattling sound," felt the helicopter "wobble" and then observed that the helicopter had struck a tree. He maneuvered the helicopter to the departure site, where he conducted a landing.

## Helicopter Strikes Hillside During Flight in Adverse Weather Conditions

**Dauphin SA 365N. Destroyed. Seven fatalities.**

The helicopter was being flown on the first segment of a three-segment charter flight in India. The crew flew the first portion of the flight at 3,000 feet and then began a climb to 6,000 feet.

The accident report said that when the pilots flew the helicopter between two hills, they were unable to maintain visual contact with the terrain because of "adverse weather conditions." (The report contained no other details about the weather.) The helicopter struck a hillside.

## Helicopter Strikes Terrain After Entanglement With Fueling Hose

**Robinson R22 Alpha. Destroyed. One minor injury.**

In preparation for a livestock-mustering flight in Australia, the pilot "hot-refueled" the helicopter (refueled the aircraft with the engine operating). Afterward, during the into-wind transition from a hover to forward flight, the helicopter rapidly rolled right and struck the ground.

A report said that during departure, the helicopter likely became entangled with the refueling hose and pump. ■

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