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FAA Outlines Transition Plan for Satellite-based Navigation and Approaches

The global positioning system will revolutionize the U.S. national airspace system. The U.S. Federal Aviation Administration plans a 15-year phase-in period to ease the transition.

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Aviation Writer

The transition to satellite-based navigation throughout the national airspace system (NAS) "will provide significant economic and safety benefits to the entire aviation community," a U.S. Federal Aviation Administration (FAA) report concludes.

The report, *FAA's Plan for Transition to GPS-Based Navigation and Landing Guidance*, gives an overview of the planned 15-year transition from today's ground-based radio navigation systems to new satellite-based navigation systems that are likely to benefit both aircraft and airports. Under that transition plan, the FAA is working with the U.S. aviation industry to augment the global positioning system (GPS), which was developed by the U.S. Department of Defense (DOD), to provide satellite-based navigation services for all phases of flight.

"Together with improved computer-based decision aids for controllers, these services will improve the safety of flight operations, accommodate user-preferred flight profiles and increase airport and airspace capacity to meet future air traffic demands," the report concludes. After the transition to satellite-navigation technology is complete, aircraft navigation will be possible with a single type of radio navigation receiver. Currently, aircraft must carry several different types of radio receivers to support navigation in different phases of flight.

The more sophisticated satellite technology will also benefit airports and flight-control operations by making possible the installation and use of new navigation, landing and surveillance services "that are not currently economically feasible."

The report says that "there will be significant reduction in the cost of equipage both to the aircraft operator and to the ground-service provider. It will be possible to phase out both the ground equipment and the associated avionics for a large number of ground-based systems ... ." Systems that could be phased out include the very high frequency omnidirectional radio range (VOR) system, distance measuring equipment (DME), the instrument landing system (ILS) and the nondirectional beacon (NDB), as well as Omega and Loran-C.

[The VOR system — a combination of transmitting stations and aircraft receivers — is the world's principal navigation system for aircraft. It is also the basis for the current high- and low-altitude aviation route (airways) structure, with airways normally consisting of routes to and from the VORs. DME, which measures the distance and bearing from a VOR that supports DME, allows an aircraft to define a two-dimensional position.

[An ILS is a precision instrument approach system that normally includes a localizer, glideslope, outer and middle markers and approach lighting. An NDB is a ground-based radio navigational aid (NAVAID) that enables a pilot, using an automatic direction finder (ADF), to determine his aircraft's location in relation to the NDB.

[Omega is a long-range navigation system that operates in the very low-frequency band. Eight Omega transmitting stations — in Norway, Liberia, North Dakota (U.S.), Hawaii (U.S.), La Reunion Island, Argentina, Australia and Japan — radiate signals between 10.2 kilohertz (kHz) and 13.6 kHz, and the pilot uses receiving equipment to determine her aircraft's position, which is based on the phase difference between the received signals.

[Loran (long-range navigation) is an electronic navigational system by which hyperbolic lines of position are determined by measuring the difference in reception times of synchronized pulse signals from two fixed transmitters. The C suffix refers to the frequency band — 100 kHz to 110 kHz — in which this type of Loran operates.]

The FAA hopes to eliminate the US$200 million annual cost of operating and maintaining the current ground-based navigation and landing-guidance systems. In contrast, the FAA estimates that the costs of operating the satellite-based system will be US$80 million annually.

GPS uses a network of satellites to determine positions. The system, operated and maintained by the DOD, consists of a constellation of two dozen satellites, as well as ground-based monitoring and control equipment. Each GPS satellite radiates precisely timed signals that are coded to allow an aircraft to determine its distance from the satellite, using the transmission time delay from the satellite, and to determine the satellite's exact position. By simultaneously receiving such signals from at least four satellites, the aircraft can determine its position.

GPS provides two different levels of service: the precise positioning service (PPS), which is available only to the DOD and other authorized government users, and the standard positioning service (SPS), which is available free of charge to users worldwide. The SPS service offers a lower level of accuracy in determining the receiver's precise position and time. The DOD, through a technique called "selective availability [SA]," controls the accuracy of the SPS system "to protect U.S. security interests," the report said.

"The DOD has committed to operating the system so that it provides a positioning accuracy of better than 100 meters [328 feet] horizontal (150 meters [492 feet] vertical) 95 percent of the time, and better than 300 meters [984 feet] horizontal (450 meters [1,476 feet] vertical) 99.99 percent of the time," the report said. Time accuracy would be within 340 nanoseconds of Universal Coordinated Time (UTC). [A nanosecond is one-billionth of a second.]

On March 29, 1996, the U.S. president issued a comprehensive national policy directive on the future management and use of GPS. Among the goals of that management are to "encourage acceptance and integration of GPS into peaceful civil, commercial and scientific applications worldwide" and to "promote international cooperation in using GPS for peaceful purposes," the directive said.

The directive also announced that "it is our intention to discontinue the use of [SA] within a decade in a manner that allows adequate time and resources for our military forces to prepare fully for operations without SA. To support such a decision, affected departments and agencies will submit recommendations in accordance with the reporting requirements outlined in this policy." The directive said that "beginning in 2000, the president will make an annual determination on continued use of [SA]."

Another policy guideline in the directive was that "we will advocate the acceptance of GPS and U.S. government augmentations as standards for international use."[1]

But reliance on a satellite-navigation system controlled entirely by the United States might not be accepted throughout the international aviation community. The FAA and the International Civil Aviation Organization (ICAO) have recognized that the primary stand-alone navigation system of the future will need to be provided by a global navigation satellite system (GNSS).

Exactly what will be included in GNSS has not yet been determined, but one possibility is the Russian Federation's global orbiting navigation satellite system (GLONASS). Combining GPS and GLONASS would create a 48-satellite constellation, doubling the number of satellites in GPS alone. Navigation equipment would have more satellites in view and could choose the satellites whose geometry was best for accurate fixes, avoiding those near the horizon or nearly in line with one another. The likely result would be even greater accuracy.[2]

The first GPS research satellite was launched in 1978, and the first operational GPS satellite went into orbit 11 years later. GPS became operable on Dec. 8, 1993, but did not meet all requirements until July 17, 1995. As a way of encouraging civil aviation use of GPS, the DOD has made commitments to maintain the system "for the foreseeable future" and to guarantee a minimum of six years' notice before moving to discontinue the system. Replacement satellites for the system are in production, ensuring that the GPS constellation can operate beyond 2010.

An aircraft pilot will be able to determine her aircraft's exact position during any phase of flight. Using line-of-sight or long-range digital communication, an aircraft system will be able to notify nearby airplanes and control towers of the aircraft's precise position.

"This will provide better situational awareness to pilots and will permit extending surveillance-based air traffic control to areas where it is not now technically or economically feasible," the report says. For example, controllers will be able to pinpoint the positions of aircraft over oceans and other remote airspace.

Phasing out some of the currently used en route radar-based surveillance systems may also be possible once the GPS is widely used.

The report predicts the new capabilities "will provide significant benefits to both aircraft operators and to the air traffic control systems [that] support their operations." Such benefits would include:

- Precise "four-dimensional" navigation, which pinpoints the three spatial dimensions plus time;

- User-preferred flight paths;

- Reduced operation standards, allowing more efficient airspace use;

- Precision-approach capabilities on all runways;

- Cost savings from phasing out existing ground-based navigation systems;

- Reduced avionics equipment costs, because a single type of navigation equipment will support navigation during all phases of flight;

- Reduced training costs, because pilots eventually will have to learn only GPS-based procedures instead of the multiple procedures used today; and,

- New and enhanced procedures and navigation techniques.

Before satellite-based navigation can be widely used for civil aviation, the report says, the current SPS must be augmented. SPS is now suitable for uses such as supplemental aircraft navigation, the report says, but the present system "fails to provide the accuracy, integrity, availability and continuity of service [that] are currently required for service as a primary-means or sole-means system in the NAS for aircraft navigation and landing guidance." The SPS system without augmentation has shortcomings in important areas:

- Accuracy, "the degree of conformance of an aircraft's measured position with its true position." The SPS meets the accuracy requirements for "en route through nonprecision approach" but not for precision approaches;

- Integrity, "the ability to provide timely warnings when all or part of the system is providing erroneous information." Although each GPS satellite broadcasts an integrity message to assure users that its signals are correct, it sometimes takes one-half hour or more for a fault to be detected and an integrity message transmitted.

  Noting that the delay is "too long for aviation use," the report says that aircraft now using the GPS system must employ a technique called "receiver autonomous integrity monitoring" (RAIM). This technique uses redundant satellite measurements to test the accuracy of the GPS signals.

  "While effective in providing integrity," RAIM is available only when the redundant satellites are in an acceptable geometry to verify signals. At times, there are RAIM holes — airspace regions where RAIM is unavailable because not enough satellites are in view;

- Availability, "the probability at any given time that the system will meet the accuracy and integrity requirements for a specific phase of flight." The potential for occasional RAIM holes caused by satellite failure means the GPS system is not always fully available; and,

- Continuity, "the probability that a [navigation] service will continue to be available" for an entire flight approach (or other phase of flight) if it is available at the beginning of that phase.

To meet these flight requirements, the FAA is developing two systems to augment GPS: the wide-area augmentation system (WAAS) and the local-area augmentation system (LAAS).

To help fill GPS gaps, the WAAS (Figure 1, page 4) closely monitors satellite signals and transmits integrity broadcasts, differential corrections and additional ranging signals to "provide the accuracy, integrity, availability and continuity required to support all phases of flight."

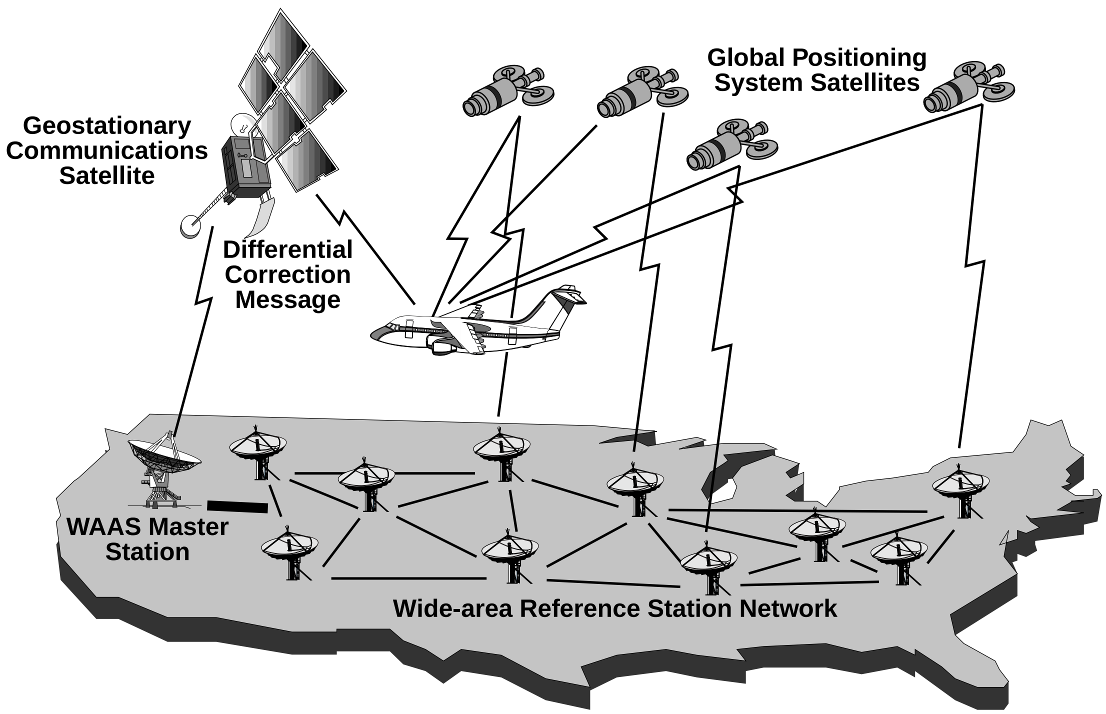
WAAS uses a network of wide-area reference stations that receive and monitor GPS signals. Data from the reference stations are transmitted to master stations, which assess the validity of signals from each satellite and compute any necessary corrections.

The validity assessment and the wide-area corrections are then transmitted, in the form of integrity messages, to aircraft via geostationary communications satellites. The WAAS signals are transmitted on the same frequency and with the same type of modulation as the GPS signal, so that the same receiver can process both signals.

The WAAS integrity messages give each user a direct verification of the signal integrity from each satellite in range. This means that the user will not need the extra satellites now required by the RAIM verification system. Because the WAAS satellite provides a ranging signal, generally only three GPS satellites will be required to compute an aircraft's exact position. "With this reduced requirement for the number of satellites in view, GPS/WAAS will meet the availability and continuity requirements for all phases of flight," the report says.

In addition, GPS/WAAS is expected to meet the accuracy requirements of Category-I precision approaches. [A Category-I precision approach provides for approach to a height above touchdown of not less than 200 feet (61 meters) and with a runway visual range of not less than 732 meters (2,400 feet), with touchdown zone and centerline lighting 549 meters (1,800 feet) (Category IA, IB and IC); or 610 meters (2,000 feet) (Category ID).]

The WAAS integrity messages will allow an aircraft's GPS/WAAS receiver to correct for both the timing and satellite-position



Source: U.S. Federal Aviation Administration

Figure 1

errors in the individual satellite signals, as well as the signal delay caused by the ionosphere.

The phase in which WAAS reaches its first operational capability, about 1998, is called initial WAAS (IWAAS). Although IWAAS will support navigation and Category-I approaches, it will not have the internal redundancy to ensure its continued availability in case of failure of elements of the system. Therefore, IWAAS will not be adequate as a sole-means navigation and approach system.

Nevertheless, the WAAS contract includes several options for expanding the system by adding satellites and ground stations. By 2001, a target date for the expansion, the WAAS "will have achieved a sufficient level of robustness to enable it to serve as a sole-means system for air navigation and landing guidance," the report says.

It is anticipated that by about 2001, WAAS will have the internal redundancy to guarantee its availability in case other elements of the system fail. This phase is called end-state WAAS (EWAAS).

As soon as the IWASS system is in place, navigation and nonprecision approaches will become more available throughout its coverage area. "The combination of additional ranging signals and ground integrity broadcast will allow GPS/WAAS to be used as the primary radio-navigation system," the report says.

In parallel with the use of WAAS for navigation, the FAA will carry out intensive testing to ensure that the accuracy of WAAS-provided corrections is adequate for precision approaches. The FAA now expects WAAS to be approved for precision approaches within three months to six months after IWAAS is in place. At first, while the FAA and aircraft users get to know the system, the minimums may be "somewhat higher than normal ILS minimums," the report says.

Using WAAS for precision approaches requires not only the signal, but also the development and flight testing of WAAS-based approach procedures. And developing those procedures will require new, high-precision data bases of the approach waypoints. By 2000, the FAA hopes to have WAAS approach procedures available, for all U.S. runways currently equipped with ILSs.

For runways and heliports that do not now have Category I-ILS approaches, the FAA plans to develop and certify WAAS-based approaches. "The technical capability will exist to provide a precision approach to essentially all qualifying runways and heliports," the report says.

But those new requirements can be met in a timely fashion only if the time it now takes to develop instrument approach procedures can be reduced. For that reason, the FAA is giving higher priority to its current automation-upgrade program for instrument approach procedures.

Although the WAAS accuracy will support precision approaches to Category-I minimums, it will be unable, by itself, to meet the minimum requirements of Category-II and Category-III precision approaches.

[A Category-II precision approach provides for approach to a height above touchdown of not less than 100 feet (30.5 meters) and with a runway visual range of not less than 366 meters (1,200 feet).

[A Category-III precision approach provides for approach without a decision height and with a runway visual range of 213.5 meters (700 feet) (Category IIIA); 46 meters (150 feet) (Category IIIB); or without a runway visual range minimum (Category IIIC).]

To help meet those more stringent requirements, the FAA is developing LAAS. Under this system, a ground-reference station will broadcast to aircraft within line of sight the necessary corrections to GPS/WAAS signals. Typically, the range of the LAAS service will be within 25 nautical miles to 30 nautical miles (46.3 kilometers to 55.5 kilometers) of the airport.

In addition to helping meet Category-II and Category-III approach requirements, LAAS can also be used at high-capacity airports "to increase service availability beyond that ensured by WAAS alone." Also, LAAS might be needed to support Category-I approaches at a few airports that cannot rely on GPS/WAAS because they are located beyond the coverage of some WAAS satellites.

Meanwhile, the avionics industry will be developing aircraft equipment to receive and process WAAS signals. In January 1996, the FAA completed the minimum operational performance standard (MOPS) for WAAS, which included full specification of the navigation modes. The MOPS is now being updated to define the precision approach modes.

The new GPS/WAAS avionics are expected to replace today's GPS avionics based on FAA technical standard order (TSO) C129. Although the current avionics system will continue to be useful for supplemental navigation and nonprecision approaches based on the TSO-C129 avionics, the system — unless it is upgraded — "will not be usable for primary/sole-means navigation nor for GPS/WAAS nonprecision or precision approaches."

GPS is being used already in some areas to enhance aircraft operations. In June 1993, following the issuance of TSO-C129, GPS was approved as a supplemental system for navigation and nonprecision approaches. Using GPS to fly an existing nonprecision approach is called an "overlay" nonprecision approach.

Although the supplemental-system approval requires that aircraft also carry a separate primary- or sole-means navigation system, the supplemental approval does allow appropriately equipped aircraft to take advantage of some GPS operational benefits, such as direct off-airways navigation.

"The increased navigational accuracy [that] GPS provides and [its] ability to define routes in three dimensions will lead to much more efficient use of the airspace," the report says. For example, GPS helps aircraft to precisely fly terminal arrival and departure routes, which improves the efficiency of traffic flow in the air-terminal area and makes it easier for aircraft to avoid noise-sensitive areas.

To realize the full benefits of the new technology, better data link–based air-ground communications and advanced automation-based controller aids, such as automated en route air traffic control (AERA) and the center terminal radar approach control (TRACON) automation system (CTAS), will be needed. "Airspace efficiencies will thus be paced by the availability of the new hardware and software required for these systems," the report says. "The goal is to provide the aircraft operator with increasing flexibility, evolving through easily changeable user-preferred routing with optimized climb and descent profiles to a nearly free-flight environment."

In such an environment, the aircraft operator will be able to choose and vary the aircraft route at will, subject only to the constraints of conflict with other aircraft and violation of restricted airspace. Today, only aircraft equipped with flight management systems that have area navigation (RNAV) capability — through avionics that use a combination of two or more DMEs, VORs or both to determine position — can take advantage of the new direct routes. Many aircraft do not have such equipment.

FAA Order 7100.10, "Air Traffic Implementation Plan For the Use of the Global Positioning System," outlines a number of initiatives the FAA is considering to help airspace users. Those steps include:

- Restructuring the existing airway system to accommodate direct routings;
- Using GPS capabilities to reduce separation standards in the U.S. en route environment;
- Developing more flexible offset route capabilities and procedures to relieve congestion on high-density air routes;
- Restructuring special-use airspace to accommodate a GPS-based en route system;
- Establishing an altitude stratum in U.S. airspace that is designated for GPS-equipped aircraft;
- Establishing a GPS-based terminal route structure;
- Using GPS capabilities to reduce terminal separation standards; and,

- Using GPS to identify, track and control aircraft and vehicles to an accuracy of one meter to three meters (3.3 feet to 9.8 feet) on an airport's surface.

The GPS system will provide the basis for what the report calls "a revolution in oceanic operations." At present, aircraft over oceans are restricted to minimum lateral separations of 60 nautical miles (111 kilometers) and longitudinal separations of 120 nautical miles (222 kilometers) because of unreliable pilot-controller communications and the limited accuracy of current means of oceanic navigation: Omega dead reckoning based on inertial navigation systems (INSs).

With GPS, aircraft that are out of range of land-based systems will have access to precision navigation. And automatic dependent surveillance — based on reportings of GPS-derived positions — will provide oceanic controllers with a radar-like display of aircraft positions.

"Over time, oceanic operations will evolve to resemble those over land, with much-reduced separations and the flexibility associated with operating in a surveillance-based air traffic control environment."

The FAA's first step in that direction was its approval in December 1994 of using GPS as a primary means of transoceanic navigation, which began in July 1995. Operations also began later that year on the Pacific future air navigation system (FANS)-1, which includes GPS-augmented navigation and satellite data-link reporting of position.

In 1997, the FANS-1 system is scheduled to allow the reduction of lateral/longitudinal separations to 50/50 nautical miles (93/93 kilometers) over the South Pacific, with a further reduction to 30/30 nautical miles (56/56 kilometers) in 1999. Meanwhile, some nations whose navigation infrastructure lagged behind that of the United States and Western Europe are moving rapidly to make GPS an integral part of their air navigation systems. For example, Fiji now bases all of its internal aircraft operations on GPS.

Today's ground-based infrastructure in the United States for aircraft navigation and guidance represents a major investment in numerous systems, such as VOR/DME, Omega and tactical air navigation (TACAN). The military's TACAN system is similar to VOR/DME, but TACAN's azimuth component operates in a different radio-frequency band than VOR. Most U.S. military aircraft use only TACAN.

Similarly, the avionics expenses related to navigation by the three principal users — air carriers, general aviation and the military — also represent significant investments.

The FAA estimates that transition costs for each of the three user communities (commercial aviation, general aviation and the military) "will be on the order of a billion dollars, excluding the costs of aircraft downtime and the retraining of air crews and maintenance personnel." FAA planners believe three prerequisites must be met before the full transition to satellite-based navigation:

- Operational benefit: Aircraft operators must be convinced that there will be sufficient operational benefits from the system before they invest in the expensive new technology;

- System performance: Aircraft operators will demand thorough analyses, flight tests and extensive operational experience that show that the system meets their requirements for accuracy, integrity and reliability; and,

- Transition period: The FAA recognizes that aircraft operators must have some time to recoup their massive investments in present-generation avionics.

The transition to satellite-based navigation will take place in three phases:

- At first, the system will be made available only on a supplemental basis, allowing users to gain confidence in the system and to begin to experience its operational benefits while conventional navigation systems are still in use. During this period, new aircraft must still be equipped with avionics for ground-based systems.

- In the second phase, which is expected to last about a decade, the FAA will certify the new satellite-based technology as a primary/sole-means system for navigation and landing guidance. At the same time, the ground-based system will continue to be a primary/sole-means system. Aircraft will be able to operate with either or both systems, but new aircraft will be equipped only with GPS/WAAS avionics; and,

- In the final phase, the conventional ground-based systems will be decommissioned, and all aircraft must be equipped with GPS/WAAS avionics to enable operation using electronic navigation.

Before the current ground-based systems can be decommissioned, all aircraft must be equipped with GPS/WAAS avionics, and both the ground-system operators and the aircraft operators must be convinced that operations using GPS/WAAS meet all required standards for safety and reliability. The system must:

- Demonstrate the overall level of reliability needed to support civil aviation operations. That means not only reliability in day-to-day operations, but also a level of redundancy to cope with failures in parts of the system, such as individual satellites;

- Be able to operate during periods of electromagnetic interference, regardless of whether the interference is naturally occurring or deliberately caused. Because of the low-level signal power received from its satellites, GPS/WAAS is especially vulnerable to radio-frequency interference (RFI). A number of federal agencies that are evaluating the degree of vulnerability have indicated that most unintentional RFI "can be adequately suppressed at the source."

But the FAA report suggests that "a prerequisite for making GPS/WAAS a sole-means system will be to develop the ability to detect, locate and suppress any interference rapidly ... ." And procedures must be in place to safely maintain aircraft separation before RFI is suppressed;

- Demonstrate functional accuracy despite ionospheric disturbances and other naturally occurring phenomena. "There is some continuing concern related to the magnitude of this (ionospheric-disturbance) effect on the accuracy of the WAAS during the peaks of the 11-year sunspot cycle," the report says. Although the experience of GPS users during the most recent sunspot peak, in 1989–1990, indicated that "these effects are manageable," the report says that "data [to be collected] during the upcoming peak period around 2001 will be important to finalizing the system parameters ... ";

- Be able to function during national emergencies. Some civil aviation officials have expressed concerns that, during a national emergency, the DOD "might use its control of GPS to deny the signal to civil users or to degrade GPS to the point where it could no longer support civil aviation." The U.S. president has ultimate control over all U.S. navigation facilities, but the report says that the U.S. government "is committed to making GPS available for both national and worldwide civil applications," and would deny the availability of navigation systems only if there were imminent risk of a direct attack on the United States; and,

- Show that it can operate during GPS-signal disruption. Other systems will be available as backups during the "extended transition period," but the FAA is looking into "procedures for coping with a possible temporary interruption of GPS/WAAS" after the other systems have been decommissioned.

For most aircraft, the installation of GPS/WAAS avionics is expected to occur in two steps: first, installing a single GPS unit as a backup to conventional avionics equipment, and later equipping the aircraft with dual GPS/WAAS avionics.

Aircraft operators would benefit from that plan because it would defer the added cost of dual equipment for five years to 10 years, and the deferral would also provide a period for technological advances in GPS/WAAS avionics.

"The operational benefits of GPS/WAAS, especially the increased routing flexibility and [the] many more precision approaches, will motivate most operators of aircraft used extensively for IFR [instrument flight rules] operations to equip with GPS/WAAS in the five-[year] to six-year period following the availability of the services," the report predicts.

If most commercial aircraft are equipped with satellite-based avionics by 2005, the current ground-based navigation systems will become backups. "Although a sufficient number of ground facilities will be maintained to allow users to complete their flight without GPS/WAAS avionics, there may be some loss in flexibility and efficiency" for aircraft that are not equipped for GPS/WAAS operations.

During the first half of the anticipated 10-year phaseout process, the FAA plans to maintain the VOR/DME system at full capability. In the second five years, however, the FAA will "selectively phase out" VOR/DME facilities in a way that will enable aircraft operators to complete flights using VOR-based navigation, with some reduction in efficiency. "At the end of the transition period (nominally 2010), remaining VOR/DME facilities will be rapidly phased out," the report says.

By the end of the transition period, about 2010, the aircraft of all operators that require 100 percent avionics reliability will have dual GPS/WAAS avionics. Aircraft that are not used for extensive IFR operations will not require the redundant WAAS avionics.

As a result of the overlay program, the GPS already can substitute for an NDB in a nonprecision approach. But the FAA phaseout strategy calls for most NDBs to maintain current capability until 2005. After 2005, the remaining NDBs "will be rapidly phased out," unless individual operators or communities are willing to assume the operation and maintenance of their local NDBs. The U.S. government plans to discontinue its support for Omega navigation systems by the end of 1997.

The U.S. government intends to discontinue Loran-C service in 2000 because GPS systems provide the same services and much of the Loran-C ground-station equipment is already nearing the end of its useful life.

An increasing number of aircraft are now using GPS as a supplemental navigation system, with avionics certified under TSO-C129. But GPS avionics that only meet those requirements cannot be approved for general use as sole-means NAS systems and, therefore, will be phased out after 2005 in favor of more advanced GPS/WAAS avionics.

The role of INSs — using on-board gyros and accelerometers to measure changes in aircraft speed and direction — will shift from navigation to flight control with the introduction of GPS. Because older INSs have relatively high maintenance costs, most aircraft owners are expected to replace them with GPS avionics.

During the next few years, Category-I ILS systems will be installed at newly qualifying runways "only if there is a clear indication that the benefits to be realized by 2005 exceed the costs," the FAA report says.

Until WAAS is certified as a sole-means approach aid (probably in 2001), the report says, aircraft needing precision-approach capability will have to be equipped with ILS receivers. Then a decade-long transition period will begin, with all Category-I ILSs remaining in service until at least 2005, after which most aircraft will be equipped with GPS/WAAS systems. After 2005, Category-I ILS systems will be gradually decommissioned (with some retained as backup systems), and in 2010, "the remaining Category-I ILSs will be rapidly phased out." Category-II and Category-III ILSs are expected to remain in place longer, depending on the results of extensive tests on the GPS/LAAS system to ensure that it will meet Category-II and Category-III accuracy requirements.

"Until certified GPS-based systems are available, the FAA plans to meet Category-II [and Category-]III requirements with ILS," the report says. The FAA will therefore continue to maintain all Category-II and Category-III ILSs "and provide new systems to meet the requirements for upgrading the capability of a system," such as an upgrade from Category I to Category II. It is expected that some GPS-based Category-II and Category-III approaches will be available by 2005.♦

Editorial note: This article was adapted from *FAA's Plan for Transition to GPS-Based Navigation and Landing Guidance*, a report by the U.S. Federal Aviation Administration, unnumbered, dated July 1996. The 28-page report includes tables, figures and illustrations, as well as list of references, an appendix of acronyms and an appendix of definitions.

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