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Satellite-based Navigation Promises to Enhance Helicopter Utility in IFR Conditions

In only four years, global positioning system (GPS) has gone from the first satellite launch to the approval of several helicopter GPS approaches. GPS will make possible nonprecision approaches to virtually any heliport regardless of the availability of ground-based navigation aids.

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The instrument flight rules (IFR) system in the United States is designed primarily for airplane use in departures, arrivals and approaches. Until now, helicopters have been tied to this fixed-wing-oriented IFR system. The global positioning system (GPS) is changing that. It allows helicopters to operate in the IFR environment on their own terms. Civilian applications of GPS will change the way helicopter pilots operate in U.S. airspace and around the world.

Although GPS was originally designed for military use, it will eventually replace ground-based navigation aids (navaids) such as very high frequency omni-directional radio ranges (VORs) and nondirectional radio beacons (NDBs). U.S. Federal Aviation Administration (FAA) Administrator David Hinson recently predicted that by the end of 1997, a GPS navigation system will be in place that will provide the sole means of navigation and of all nonprecision approaches.[1]

In 1989, the U.S Department of Defense (DoD) launched the first GPS NavStar satellite. Initial operational capability (IOC) was declared by DoD Secretary Les Aspin on Dec. 8, 1993.[2] IOC means that the 24 satellites that make up the navigation system are operating in their assigned orbits and providing signals for navigational use. The FAA declared GPS operational for certain civil IFR applications on Feb. 17, 1994.[3] On June 30, 1994, the first helicopter GPS instrument approach was approved at the Erlanger Medical Center, Chattanooga, Tennessee, U.S.

GPS is a satellite-based radio navigation system that uses precise range measurements from the GPS satellites to determine position anywhere in the world. The GPS constellation consists of the 24 satellites in various orbital planes approximately 11,000 nautical miles above the earth, broadcasting a timing signal and data message. Airborne GPS receivers measure how long a radio signal takes to reach the receiver from each satellite. By knowing the precise location of each satellite and matching timing with the atomic clocks on the satellites, the receiver can accurately measure the time the signal takes to arrive at the receiver and thus determine position.

The GPS system consists of:

- A space segment in which a minimum of four satellites must be "in view" to determine an accurate three-dimensional position. Five satellites are necessary to provide integrity monitoring;

- A control segment (five land-based monitoring and control stations). The DoD operates the GPS satellite constellation and monitors the satellites to ensure proper operation. Every satellite's exact measured orbital parameters are sent to the satellite for broadcast as part of the data message in the GPS signal; and,

- A user segment (GPS receiver-equipped air/sea/land users). Navigational values, such as distance and bearing to a waypoint, ground speed, etc., are computed from the aircraft's latitude and longitude and the location of the waypoint. [4]

The DoD, using selective availability (SA), can artificially create a significant clock error in the satellites. This feature is designed to deny an enemy the use of precise GPS position data. SA is the largest source of error in the GPS system. This degraded signal is broadcast for civilian use and is known as "CA-code."

By IOC declaration, DoD guarantees that its satellites will provide civil users a nominal lateral positioning accuracy of 328 feet (100 meters) 95 percent of the time, and 984 feet (300 meters) 99.99 percent of the time.

Vertical position accuracy is assured at 512 feet (156 meters) 95 percent of the time and 1,640 feet (500 meters) 99.9 percent of the time.

The nondegraded "P-code" is used by the military and provides 69-foot (21-meter) accuracy. Testing to date has determined that GPS accuracy is superior to traditional ground-based navaids. In-flight evaluations for nonprecision approaches by the U.S. Air Force Instrument Flight Center at Randolph Air Force Base demonstrated P- Code GPS to be well within the lateral confines of protected airspace provided for today's localizer approaches.[4]

As a service to the civilian community, the DoD is providing the GPS CA-code free of charge to civil aviation for the next 10 years. To allay any concerns over the long-term availability of GPS, civil users will be notified six years in advance of any termination or alteration of the CA-code. As a result, the FAA is rapidly bringing GPS into the national airspace system.

Currently, the FAA has approved GPS for IFR navigation for en route and terminal operations, and nonprecision approaches for aircraft equipped with the appropriate technical standard order (TSO) equipment.

The potential for GPS as a primary navaid is immense. Restructuring the airspace system to permit direct routing, reduced separation and parallel tracks is possible. The influence on helicopter operations may be even greater. GPS has demonstrated the capability to provide nonprecision approaches at any heliport regardless of available ground-based navaids.

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Dave Carter, director of safety and flight operations at the U.S.-based Helicopter Association International (HAI), sees the advent of GPS benefiting the helicopter industry in two major areas: "When given the choice of operating IFR in the existing route structure to airports, many helicopter pilots choose to fly under the weather to their intended off-airport destinations. GPS will provide route structures and approaches that are much more usable by helicopter pilots. The result will be that they will be operating in a safe, structured IFR environment, especially during marginal weather situations. In addition, as pilots become more comfortable with [helicopter] IFR routes, they will tend to use them for both VFR [visual flight rules] and IFR. By operating at IFR altitudes, noise complaints, a serious problem in the helicopter industry, will diminish. This combination of increased safety and reduced noise will greatly benefit the industry." [5]

GPS integrity is the ability to provide a timely warning to users when the system should not be used for navigation. For example, a VOR station provides system integrity by removing a signal from use and displaying an "off" flag within 10 seconds in the aircraft's navigation receiver.

GPS signal integrity is provided by receiver autonomous integrity monitoring (RAIM). This is necessary because delays of up to two hours may occur before an erroneous satellite transmission can be detected and corrected by the satellite control segment. RAIM performs a continuous comparison of the position fixes computed from all satellites in view, and prohibits the use of any that are out of tolerance. In addition, predictive RAIM uses the aircraft's projected track to determine if the satellite geometry at the destination will be sufficient to support an approach at the estimated time of arrival (ETA). Availability of RAIM detection capability to meet nonprecision approach requirements in the United States is expected to exceed 99 percent.[6]

GPS equipment used for IFR operations must incorporate an updateable navigation data base containing at least the areas in which IFR operations will be conducted, including airports, VORs, NDBs, waypoints, intersections, standard instrument departures (SIDs), and standard terminal arrival routes (STARs). Equipment certified for approaches must also include waypoints and intersections included in the nonprecision instrument approaches procedures.

Instrument approaches must be conducted using a current data base. User entry or modification of the navigational data base is not permitted, nor is it possible. (This does not preclude the storage of additional user-defined data within the equipment.)

Other limitations apply to the use of GPS equipment for IFR operations:

1. The GPS navigational equipment used must conform to TSO C-129 or equivalent.

2. GPS en route and terminal IFR operations require that the aircraft be equipped with an alternate means of navigation appropriate to the flight. This requirement can be met with an independent VOR receiver. (Active monitoring is only required if RAIM capability is lost.)

3. FAA approval of GPS equipment does not constitute approval to conduct GPS-based navigation in airspace controlled by non-U.S. authorities.

4. Procedures must be established for use when the loss of RAIM is predicted to occur. When this is encountered, the flight must rely on other approved equipment, or be delayed or canceled.

5. Aircraft navigating by GPS are considered to be area navigation-equipped (RNAV) aircraft and the appropriate suffix must be included in the flight plan.

6. Prior to any GPS IFR operation, the pilot should request and review appropriate notices to airmen (NOTAMs) with regard to possible satellite outages.[3]

The FAA's GPS Approach Overlay Program accelerates the availability of nonprecision instrument approach procedures that can be flown under IFR. It permits pilots to use GPS under IFR for flying existing nonprecision instrument approaches, except localizer, localizer-type directional aid (LDA) and simplified directional facility (SDF) procedures. Stand-alone GPS approaches are also being introduced into the airspace system. Authorization to fly approaches under IFR using GPS requires:

1. The use of avionics with TSO C-129 class A1, B1, B3, C1 or C3 authorization;

2. That the approach to be flown must be retrievable from the navigation database; and,

3. That any required alternate airport must have an approved instrument approach procedure other than GPS or Loran-C, which is anticipated to be operational at the estimated time of arrival (ETA) at the alternate.[3]

The three phases of the approach overlay program are:

Phase I. Phase I began when TSO C-129–certified avionics became available, but before IOC was declared. During Phase I, GPS could be used as the IFR flight guidance system for approaches as long as the required ground-based navaids were operational and actively monitored.

Phase II. Phase II began when IOC was declared. During this phase, GPS avionics can be used as the IFR flight guidance system for a nonprecision approach without actively monitoring the ground-based navaids that define the approach. Nevertheless, the ground-based navaids must be operational and the related avionics must be installed and operational, but need not be turned on during the approach.

The subtitle "(GPS)" is added to nonprecision approach plates to indicate that the GPS approach overlay information has been applied to the chart. The addition of "(GPS)" also advises that the approach procedure is included in the airborne navigational data base. An airport identifier is added to the chart heading to help select the appropriate airport information from the GPS database. Approaches must be requested and approved using the published title of the existing procedure such as "VOR Rwy 36." (For example, some approaches will be included in Jeppesen's NavData base before the corresponding charts are modified. The absence of "(GPS)" on a Jeppesen chart does not preclude the pilot from flying that GPS approach as long as the equipment is properly certified and the procedure to be flown is retrievable from the airborne navigation data base.)

Phase III. The FAA began Phase III of the GPS Approach Overlay Program in 1994. Phase III does not require ground-based navaids to be operational, nor does it require conventional airborne avionics to be installed or operational. GPS Avionics approved under TSO-129 A1, B1, B3, C1 or C3 are all that is required for flying an approved approach. An approved approach is titled "or GPS" and is contained in the airborne navigational data base. GPS approaches will be requested and approved using the GPS title, such as "GPS Rwy 1."

Jeppesen will add GPS Phase III information to approach plates as they are reissued. Nevertheless, because of the large number of approaches expected to be approved in the near future, Jeppesen is providing a listing of approved Phase III GPS approaches that have not yet been issued with the "or GPS" title added to the chart. This listing is found behind the "terminal" tab of the Airway Manual.

The first U.S. private stand-alone IFR approaches using GPS were published for use by Continental Express into Aspen and Steamboat Springs, Colorado, U.S. in December 1993. The first U.S. public-use stand-alone GPS approach was published in July 1994 at Frederick, Maryland, U.S. Public stand-alone GPS approaches have also been published at Oshkosh, Wisconsin, U.S. and Denton, Texas, U.S. More are in process and should be available in the near future. FAA publication of U.S. Federal Aviation Regulations (FARs) Part 97 GPS approaches will be developed and authorized on a case-by-case basis.

On June 30, 1994, the first private helicopter U.S. GPS instrument approach was approved at the Erlanger Medical Center in Chattanooga, Tennessee. Since then two more U.S. helicopter GPS approaches have been approved, one at Petroleum Helicopter's (PHI) Morgan City Heliport, Louisiana, and the other at the University of Wisconsin at Madison, Wisconsin. A fourth approach, at the Mayo Clinic in Rochester, Minnesota, is currently undergoing the approval process. The PHI approach is approved to near-precision minimums of 300 feet (91 meters) minimum descent altitude (MDA) and one-half mile visibility.

Table 1
Global Positioning System (GPS) Equipment Classes

Class A

Incorporates RAIM (receiver autonomous integrity monitoring) and an internal navigational data base.

(1) includes en route and terminal operations and nonprecision approach capabilities.
(2) provides en route and terminal operations capabilities only.

Class B

Incorporates a GPS sensor that provides data to an integrated navigation system such as flight management systems (FMS) or multisensor navigation systems.

(1) includes RAIM and provides en route and terminal operations and nonprecision approach navigation capabilities.
(2) includes RAIM and provides en route and terminal operations capabilities only.
(3) requires the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides en route and terminal operations, and nonprecision approach capabilities.
(4) equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides en route and terminal operations capabilities only.

Class C

Incorporates a GPS sensor that provides data to an integrated navigation system, such as FMS or multisensor navigation systems, which provides enhanced guidance to an autopilot or flight director to reduce flight technical error. Installation of Class C equipment is limited to aircraft approved under FARs Part 121 or equivalent criteria.

(1) includes RAIM and provides en route and terminal operations and nonprecision approach capabilities.
(2) includes RAIM and provides en route and terminal operations capabilities only.
(3) needs the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides en route and terminal operations and nonprecision approach capabilities.
(4) needs the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides en route and terminal operations capabilities only.[6]

Source: Joel S. Harris

According to Mel Hughes, a pilot who flies Erlanger Medical Center's single-pilot Bell 412, more than 30 GPS IFR approaches have already been made bringing patients into the Medical Center. Hughes says that flying GPS approaches actually reduces pilot workload: "All GPS approaches are retrievable from the data base, so no programming is required. After the pilot selects an approach, he is prompted to input the initial starting point. After that, it's all automatic. The pilot is even warned by an eye-level flashing alert 15 seconds prior to waypoints or course changes. If the HSI [horizontal situation indicator] is not reset during course changes, the pilot is again prompted to 'Turn Course Heading.'"

Hughes said GPS will prove to be a great resource for the emergency medical service (EMS) community. "Our program services hospitals in the Sequatchie Valley, which is separated from Chattanooga by a ridge line," he said. "Although several of the towns in the valley have airports, they do not have IFR approaches. When the weather is too bad to get over the ridge line, those hospitals go unserviced. A point-in-space GPS approach will allow us to safely service the hospitals in the valley when weather conditions would otherwise prevent it." (The point-in-space approach is currently undergoing the certification process.)[7]

So far, the helicopter approaches that have been approved by the FAA have been certified to helicopter R-NAV terminal instrument procedures (TERPS) criteria. Data collected by the FAA during the certification process will allow rewriting helicopter TERPS to more accurate GPS standards. The new TERPS are expected to be published in 1995. Said author Guy Maher: "Finally, helicopters are escaping the mandate to go where airplanes have to go when flying IFR."[8]

While CA-code accuracy is suitable for nonprecision approaches and en route navigation, it must be enhanced by ground-based stations to be used for precision approaches. There are two methods of improving GPS accuracy to precision approach levels. They are local area differential GPS (LDGPS) and wide area augmentation system (WAAS).

The LDGPS consists of ground stations located near major airports. Each station is installed at a precisely surveyed site. After receiving the satellites' signals, the LDGPS station compares the signal with its known location and broadcasts a correction or "differential." This broadcast is limited by line of sight to aircraft in the local area. This correction, when applied to the aircraft's GPS data, results in extremely precise positioning information.

WAAS requires a network of ground stations, probably located at the 24 existing ATC centers, to collect data from GPS satellites as they cross the United States. Differential corrections and satellite integrity data would be sent to one or more communications satellites in geostationary orbits. These data would then be broadcast to GPS-equipped aircraft. The airborne receivers would make the differential corrections automatically.

WAAS would enhance the accuracy of GPS and may eliminate the need for independent on-site differential correcting stations (LDGPS).

The FAA estimates that the WAAS system should be able to provide 16 feet (5 meters) of accuracy 95 percent of the time, and 6.5 seconds of integrity warning, thus enabling Category I precision approaches at every runway and heliport in the United States.[1] A U.S. National Aeronautics and Space Administration (NASA) Black Hawk helicopter is currently testing precision helicopter GPS approaches at San Jose, California.

Meanwhile, the FAA is determining the feasibility of using satellite-based systems for precision approaches down to Category II and III minimums. In the event that LDGPS or WAAS or some combination thereof cannot be adapted for Category II and III, the United States will continue to use ILSs.

The future of helicopter operations may have considerably brightened with the advent of GPS. If the FAA continues its aggressive policy to implement GPS, and has the funding to do so, the helicopter's safety, utility and public acceptance will be improved. ♦

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