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Report to the Committee on Transportation and Infrastructure, House of Representatives

May 1995

NATIONAL AIRSPACE SYSTEM

Comprehensive FAA Plan for Global Positioning System is Needed

GAO/RCED-95-26

GAO

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Resources, Community, and
Economic Development Division

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May 10, 1995

The Honorable Bud Shuster
Chairman
The Honorable Norman Y. Mineta
Ranking Democratic Member
Committee on Transportation
and Infrastructure
House of Representatives

The Federal Aviation Administration (FAA) is augmenting (enhancing) the Department of Defense's (DOD) Global Positioning System (GPS) because this satellite-based system will provide major benefits to civil aviation. When fully integrated as a navigation aid in the air traffic control system, GPS will be superior to the ground-based navigation aids in current use, thereby enabling civil aircraft to fly more fuel-efficient routes.

GPS satellites transmit radio signals that allow properly equipped air, land, and sea users to calculate the time and their position and speed in any location and weather condition. Because it was designed for military purposes, however, GPS does not satisfy civil air navigation requirements dictating, for example, that the system's signals be available in sufficient number virtually all of the time and be accurate enough to support aircraft landings in the worst weather conditions. When augmented by wide and local area systems that FAA intends to implement,[1] GPS is expected to satisfy the above requirements.

After FAA established its schedule in February 1992 for using GPS to support civil air navigation, governmental and aviation industry groups recommended that the agency accelerate some of the schedule's milestones to permit full use of the system by civil aviation as soon as possible. In January 1994—following the recommendations of an industry task force on satellite navigation and The National Commission to Ensure a Strong Competitive Airline Industry—the Secretary of Transportation charged the FAA Administrator with, among other things, accelerating the use of GPS by civil aviation.

In response, FAA modified its schedule for using GPS by accelerating several milestones, in general, from 2000 to 1997. As a result, your offices asked us

[1]The wide area system will use commercial communication satellites to augment GPS' signals in the airspace between and around airports so that civil aircraft can navigate in air routes and land on airport runways. The local area system will use ground-based communications equipment to augment the signals in the airspace around airports so that aircraft can land in the worst weather conditions.

to assess whether FAA will have sufficient time under the new milestones to augment GPS and whether the agency has taken appropriate actions to better manage its GPS-related efforts.

Results in Brief

Although FAA has met all of its milestones to date, the agency will face more complex and difficult tasks in achieving future milestones. We are concerned that the revised schedule will not give the agency enough time to develop and implement its wide area system for augmenting GPS by 1997, when civil aircraft are expected to use the augmented GPS without having to rely on other navigation aids for backup. This commitment is ambitious because the FAA contractor must develop and implement the wide area system, and the agency must accept and commission it over a 28-month period—although FAA estimates that software development alone may take from 24 to 28 months. Also, FAA's efforts to develop and implement the wide area system may be slowed by potential difficulties—some of which are beyond FAA's control. For example, the launching of the commercial communication satellites needed to support the system may be delayed.

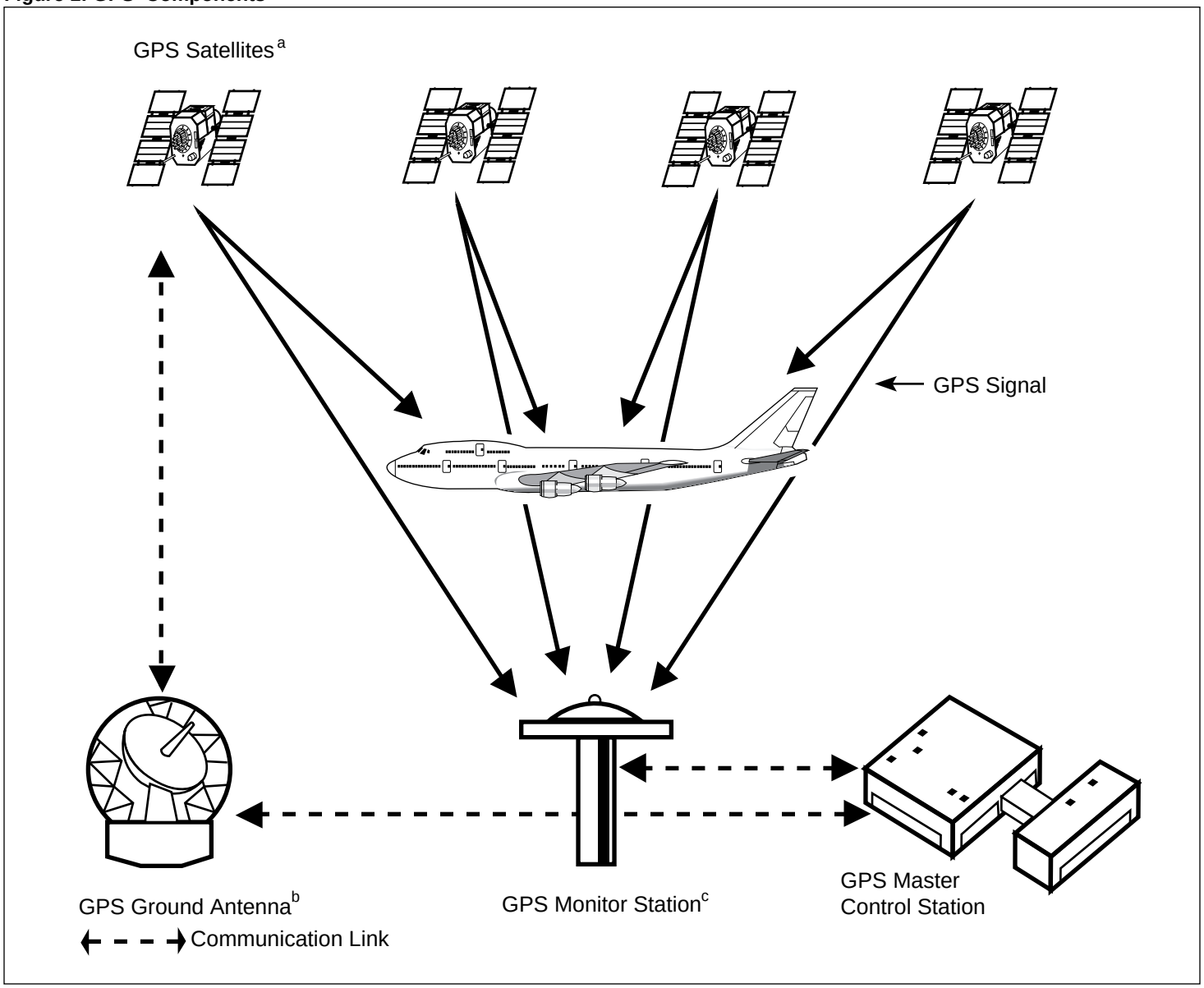
FAA took several actions in 1994 to strengthen its ability to manage its GPS efforts. FAA's actions include integrating GPS activities within the agency, securing the necessary funding to accelerate the development of the wide area system, and issuing plans for developing and implementing augmentation systems. These actions are encouraging. However, the plans for GPS are not comprehensive because they do not provide complete or detailed schedule and cost information, needed for making sound programmatic and budgetary decisions regarding these augmentation systems. The plans omit (1) milestones for implementing the local area system to augment GPS, (2) cost estimates for this system and the wide area system, and (3) information on the probabilities of meeting schedule and cost estimates, given known potential problems that may affect the development of these systems.

Background

DOD designed GPS to support military missions, such as military air, land, and sea navigation; missile guidance; search and rescue; mine placement; and precision surveying. GPS has space and ground components, as depicted in figure 1. The space component consists of a worldwide constellation of 24 satellites in six orbits at approximately 11,000 miles above the earth. These satellites are positioned so that a user will have at least four satellites in view at any given location. The satellites transmit

radio signals that permit adequately equipped users to calculate the time as well as their speed and tridimensional position (latitude, longitude, and altitude) anywhere on or above the earth's surface and in any weather condition. The ground component includes a master control station, five monitoring stations, and three ground antennae located throughout the world. The master control station tracks and directs the GPS satellites through the monitoring stations and ground antennae, respectively.

Figure 1: GPS' Components



[a]Other GPS satellites not shown.

[b]Other GPS ground antennae not shown.

[c]Other GPS monitoring stations not shown.

Source: Based on DOD's data.

As mentioned earlier, because GPS was designed for military purposes, the system, by itself, cannot satisfy key safety-related civil air navigation requirements, such as those dictating that a sufficient number of the system's satellite signals be available virtually all of the time. Currently, GPS is used domestically as a supplemental means of navigation because on-board-the-aircraft augmentation systems—which use altimeters, gyroscopes, and other equipment to augment GPS—do not address all civil air navigation requirements, particularly those related to the system's availability.

In accordance with the direction provided by the Department of Transportation (DOT), FAA is supporting the development of a wide area system and local area systems that will permit GPS to fulfill all civil air navigation requirements and become a primary means of navigation.[2] This month, FAA plans to award a contract for developing the wide area system. The agency has not announced a date for awarding a contract to develop local area systems. (See app. I for a description of civil air navigation requirements and the wide and local area systems that FAA intends to implement.)

FAA and the aviation industry expect that the augmented GPS will result in a navigation capability that will provide major benefits to the agency, civil aviation, and others because of its superiority over currently used navigation aids. For example, because FAA expects that the augmented GPS will be able to support runway approaches and landings in all weather conditions, the agency recently canceled its multibillion-dollar project to acquire microwave landing systems—a key element of the program to modernize the air traffic control system.[3] Also, FAA foresees that the augmented GPS will permit the agency, after a transition period, to start decommissioning its ground network of navigation and landing aids. Moreover, airlines expect that the augmented GPS and its applications will result in major operational and economic benefits by reducing flying times and fuel consumption. In addition, DOT and FAA anticipate that the augmented GPS will benefit not only aviation users but also other federal

[2]DOT's direction to FAA agrees with the recommendations proposed in two reports: A Report to the Secretaries of Defense and Transportation, The Global Positioning System: Management and Operation of a Dual Use System, Joint DOD/DOT Task Force (Dec. 1993) and A Technical Report to the Secretary of Transportation on A National Approach to Augmented GPS Services, Department of Commerce, National Telecommunications and Information Administration (NTIA), NTIA Special Pub. 94-30 (Nov. 1994).

[3]Our report Airspace System: Emerging Technologies May Offer Alternatives to the Instrument Landing System (GAO/RCED-93-33, Nov. 13, 1992) discusses the need for FAA to reassess its requirements for precision landing systems. (See fn. 2.)

agencies and land and sea users having a need for navigation information.[4]

FAA May Not Achieve Future GPS Milestones

Although FAA has met all milestones for GPS to date, the agency will face more complex and difficult tasks in achieving future milestones. We are concerned that the revised schedule for augmenting GPS will not give the agency enough time to develop and implement the wide area system by 1997, when civil aircraft are expected to use the augmented GPS domestically as a primary means of navigation. The schedule is tight, and potential problems could affect the system's development and implementation.

FAA Has Met Initial GPS Milestones

In 1993, FAA met several milestones for GPS when the agency approved the use of the system as a supplemental means of navigation for oceanic and domestic air routes as well as nonprecision approaches.[5] Also, in December 1994, FAA met one of two 1995 milestones ahead of schedule when the agency approved the use of GPS—augmented by on-board-the-aircraft systems—as a primary means of navigation over oceans and remote areas.[6] In addition, FAA will likely meet the other 1995 milestone when the agency completes assessing the feasibility of using local area systems to support all types of precision approaches.[7] Agency officials responsible for GPS activities see little chance for delays in meeting this milestone.[8]

[4]One of our recent reports highlights the need for a governmentwide response to the GPS needs of federal agencies. See Global Positioning Technology: Opportunities for Greater Federal Agency Joint Development and Use (GAO/RCED-94-280, Sept. 28, 1994).

[5]On a nonprecision approach, an aircraft receives electronic guidance for flying toward the runway's centerline. On a precision approach, an aircraft receives not only this guidance but also guidance on the slope of descent to the runway. As a result, on a precision approach, an aircraft can safely descend closer to the ground while attempting to land in bad weather.

[6]These augmentations must have an automatic dead reckoning navigation capability, which uses airspeed, altitude, and heading information to guide the aircraft in case GPS is not available. Also, these augmentations must be enhanced by operational procedures and, when GPS is not available, be operated with restrictions.

[7]According to FAA, its augmentation systems will permit aircraft to rely solely on GPS for flying precision approaches. The wide area system is expected to support Category I precision approaches, under which an aircraft receives guidance as it descends to a height of 200 feet when the runway's visibility is at least 1,800 feet. The local area systems are expected to support not only these precision approaches but also Category II and III precision approaches, under which an aircraft receives greater navigational assistance when approaching a runway.

[8]These officials include the Director of the Integrated Product Team for GPS and Navigation, the Manager of the Satellite Navigation Program, and the Manager of the Wide Area Augmentation System Project.

Although FAA has been confident for some time that local area systems will be able to support all types of precision approaches, the agency is sponsoring research by various institutions to confirm the feasibility of these systems. For example, in June 1994, FAA awarded contracts to Wilcox Electric Inc. and E-Systems to develop and test two different local area systems for supporting precision approaches. According to FAA officials responsible for GPS activities, the preliminary testing of demonstration systems has been encouraging. These agency officials expect that the reports on the performance of these systems will be completed on schedule by the summer of 1995.

FAA May Not Meet Future GPS Milestones

FAA may not be able to meet its 1997 milestones for civil aircraft to use GPS domestically as a primary means of navigation. These milestones are based on the implementation of an initial wide area system by 1997. (See app. II for a depiction of FAA's milestones for GPS.) The schedule for implementing the initial system is tight, and potential problems could affect the system's development. This commitment is challenging because the system's schedule may not provide enough time for FAA to complete all necessary steps. Over a 28-month period, from May 1995 to September 1997, the FAA contractor must develop and implement the system, and the agency must accept and commission it. However, FAA estimates that the system's software development alone may take from 24 to 28 months, thereby leaving little time for the agency to accept and commission the system.

Also, potential difficulties may be encountered during the system's development. These difficulties include the following:

- Software-related problems. Although FAA has taken measures such as strengthening its oversight capabilities, the contractor selected may face difficulties while attempting to develop, integrate, test, and certify the wide area system's software. The agency estimates that when measures to mitigate potential software development problems are considered, the software schedule has about a 60-percent probability of success. FAA has noted its concerns about potential software problems since it decided to adopt the accelerated schedule for developing and implementing the system.
- Satellite-related problems. The space component of the wide area system requires that three commercial communication satellites be in place by late 1997—an undertaking that is beyond FAA's control. However, enough satellites may not be in orbit on time because the International Maritime

Satellite Organization (INMARSAT)—the only commercial entity that has publicly announced its intention to launch satellites capable of supporting this space component—could delay launches or could launch an insufficient number of satellites to fully support this component. INMARSAT recently delayed launching the first of these satellites from late 1995 to early 1996 because the rocket to launch the satellite would not be available on schedule.

FAA recently estimated that its 1997 milestones may slip up to 18 months if potential problems are realized. However, the agency did not provide information on the likelihood of meeting the milestones within this period of time.

FAA's Actions Are Encouraging, but Plans Provide Incomplete Information to Decisionmakers

In 1994, FAA took several actions to strengthen its capacity to manage its GPS-related efforts, including integrating GPS activities within the agency, securing additional funding to develop the wide area system, and issuing plans for developing and implementing the augmentation systems and a draft plan for transitioning to GPS. These actions are encouraging. However, the plans are not comprehensive because they exclude schedule and cost estimates for implementing augmentation systems and information on the likelihood of achieving these estimates.

FAA Has Improved Its Ability to Augment GPS

FAA recently took several management actions to better position itself for augmenting GPS. First, FAA integrated pertinent GPS research, development, and acquisition activities that had been fragmented across the agency. In October 1993, FAA named a Director of GPS/Communications, Navigation, and Surveillance (CNS) Systems, and in May 1994, it created the GPS/CNS Development and Implementation Service. In November 1994, FAA consolidated the Service with units responsible for current ground-based navigation aids, such as instrument landing systems. This new organization, headed by the former Director of the GPS/CNS Service, is called the Integrated Product Team for GPS and Navigation and is under the jurisdiction of the Associate Administrator for Research and Acquisitions. According to the head of this organization, the consolidation was intended to improve the integration and coordination of the agency's efforts to augment GPS.

Second, after deciding to accelerate the implementation of the wide area system, FAA obtained $82.8 million for fiscal year 1995, an increase of $61.9 million over its appropriation for fiscal year 1994. This funding

includes $67.9 million to develop and implement the wide area system. In fiscal year 1996, the administration is requesting $86.9 million to fund the system.

Third, in mid-1994, FAA released plans for guiding the development, acquisition, and implementation of GPS' augmentations and drafted an agencywide plan for directing the transition to GPS.[9]

Although these actions are encouraging, they may not address potential problems that may affect the development of the wide area system. Some of these problems are beyond FAA's control, such as the difficulties that may be experienced during the launching of commercial communication satellites.

GPS-Related Plans Provide Insufficient Information

Among other things, the GPS development and implementation plans and the draft of the transition plan (1) present information on FAA's planned efforts to augment GPS, including schedule information on the wide area system and related milestones for using GPS as a primary means of navigation; (2) identify requirements that GPS must satisfy; and (3) highlight benefits that GPS will provide the agency and aviation users. Also, after the wide and local area systems are implemented, the transition plan proposes tentative schedules for transitioning to GPS and for decommissioning navigation aids in current use.

However, these plans provide insufficient information to decisionmakers in the administration and the Congress on the systems needed for augmenting GPS.

- The plans issued in 1994 do not provide a timetable for implementing local area systems that will be needed to support precision approaches. FAA recently canceled its microwave landing system project because it is confident that the local area systems will be able to support all types of precision approaches. Without a timetable, decisionmakers cannot evaluate the extent to which schedules being considered are timely and minimize the need to keep instrument landing systems operational.
- The GPS plans exclude information on the level of financial resources needed by FAA to implement the wide area system. Also, they do not present information on the funding required to implement the local area systems needed for supporting precision approaches.

[9]FAA Satellite Navigation Program Master Plan, FY 94-99, June 15, 1994; GPS Implementation Plan for Air Navigation and Landing, Aug. 1994; and FAA National GPS/CNS Transition Plan, Draft, July 1994.

When plans do not identify financial resource needs, past experience shows that decisionmakers may not have a sound basis for assessing budget requests or considering alternative courses of action. For example, because FAA's 1992 GPS development plan did not include cost information,[10] the Congress did not have the necessary information to evaluate the administration's budget request for funding FAA's GPS effort for fiscal year 1993. After we reported to the Congress that this budget request was less than half of what FAA needed to keep these efforts on schedule, the Congress had a basis to fully fund the agency's needs.[11]

- The plans omit information on the likelihood that FAA will meet its milestone and cost estimates, given the effect of potential problems on the system's development and implementation. Identifying the probability (low, medium, and high) of successfully meeting the schedule and cost estimates would enable decisionmakers to understand the level of confidence that the agency has in these estimates.

FAA has the above information for the wide area system. Also, according to agency officials responsible for GPS activities, FAA expects to complete the development of similar information on the local area systems by late 1995.[12]

Conclusions

FAA has been successful in meeting its GPS milestones to date. However, the agency faces more complex and difficult tasks in achieving future milestones. We are concerned that the revised schedule will not give the agency enough time to develop and implement the wide area system by 1997, when civil aviation is expected to use the augmented GPS as a primary means of navigation.

To strengthen its ability to manage its GPS efforts, FAA recently took various actions, such as integrating GPS activities across the agency,

[10]FAA's 1992 Research and Development Satellite Navigation Plan.

[11]See Hearing on the Department of Transportation and Related Agencies Appropriations for 1993, before the Subcommittee on the Department of Transportation and Related Agencies, Committee on Appropriations, U.S. House of Representatives (102nd Cong., 2nd Sess., Apr. 6, 1992) and Airspace System: Emerging Technologies May Offer Alternatives to the Instrument Landing System (GAO/RCED-93-33, Nov. 13, 1992).

[12]FAA recently submitted to the Congress comprehensive air traffic control automation plans, including sensitive schedule and cost information regarding system procurement. However, these plans did not provide information on the likelihood that FAA would meet its schedule and cost estimates. See Air Traffic Control Automation Program Master Plan, Sept. 27, 1994, and Office of Air Traffic Systems Development, Program Master Plan, Feb. 3, 1995.

securing additional funding for accelerating the development of the wide area system, issuing development and implementation plans, and drafting a transition plan. These actions are encouraging. However, the plans are not comprehensive enough to provide the administration and the Congress with a sound basis for making programmatic and budgetary decisions concerning GPS' augmentation systems. For example, the plans omit important schedule and cost information on these systems.

A comprehensive plan—including (1) complete milestones for augmenting GPS and transitioning to it, (2) the financial resources needed to achieve those milestones, and (3) information on the likelihood that FAA will meet its milestone and cost estimates—would help FAA guide and coordinate its efforts, marshall its resources, and assess its progress. Also, this plan would help the administration and the Congress ascertain the scope of FAA's efforts, in terms of schedules and costs; assess whether the agency can meet milestones on time, given the level of resources requested; consider alternative courses of action; and monitor whether the agency's progress toward accomplishing these milestones and transitioning to GPS is on schedule and within budget. Finally, the plan would help aviation users map out their transition to GPS in terms of both equipping aircraft and training pilots. With the development of additional information on local area systems by late 1995, FAA will soon have the information needed to prepare a comprehensive GPS plan.

Recommendation

We recommend that the Secretary of Transportation direct the FAA Administrator to prepare a comprehensive plan for augmenting GPS and transitioning to it and to update this plan regularly. The plan should include, among other things, schedule and cost estimates for developing and implementing the wide and local area augmentation systems as well as information on the probability that FAA will meet these estimates.

Agency Comments

We gave copies of the draft report to DOT and FAA officials, including FAA's Director of the Integrated Product Team for GPS and Navigation, the Manager of the Satellite Navigation Program, the Manager of the Wide Area Augmentation System Project, and the Manager of the Local Area Augmentation System Project. These officials generally agreed with the report's findings, conclusions, and recommendation and did not have concerns about its contents. The officials gave us information and suggestions to help us clarify and qualify the report. We incorporated their suggestions where appropriate.

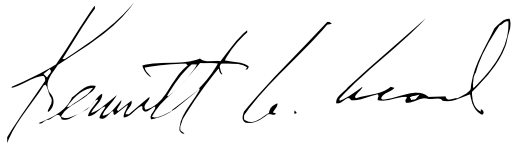
Scope and Methodology

We obtained information on FAA's efforts to augment GPS from FAA officials responsible for pertinent GPS activities, including the Director of the Integrated Product Team for GPS and Navigation and the Manager of the Satellite Navigation Program. Also, we reviewed key documentation on civil air navigation requirements, reports on different augmentation systems being developed to augment GPS, plans and studies that identified various time frames for augmenting GPS, and schedule and cost information on FAA's efforts related to GPS. In addition, we attended various professional meetings sponsored by FAA and other aviation organizations at which GPS issues were discussed. Finally, we obtained information on satellite navigation technology through discussions with representatives from airlines, the Air Transport Association, the Aircraft Owners and Pilots Association, the GPS industry, the International Civil Aviation Organization (ICAO), and DOD, including the Executive Secretary of the U.S. GPS Industry Council; the Chairman of ICAO's Special Committee on Future Air Navigation Systems, Phase II; and the Senior Staff Specialist for Navigation and Air Traffic Control Systems in the Office of the Assistant Secretary of Defense. We conducted our work from August 1993 through April 1995 in accordance with generally accepted government auditing standards.

As arranged with your offices, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies to interested congressional committees; the Secretary of Transportation; the Administrator, FAA; the Director, Office of Management and Budget; and other interested parties. We will also make copies available to others upon request.

This work was performed under the direction of Allen Li, Associate Director, who may be reached at (202) 512-3600 if you or your staff have any questions. Major contributors to this report are listed in appendix III.

Sincerely yours,



Kenneth M. Mead
Director, Transportation and
Telecommunications Issues

Contents

Abbreviations

CNS	Communications, Navigation, and Surveillance
DOD	Department of Defense
DOT	Department of Transportation
FAA	Federal Aviation Administration
GAO	General Accounting Office
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
INMARSAT	International Maritime Satellite Organization

Civil Air Navigation Requirements and GPS' Augmentations

The Global Positioning System (GPS), by itself, cannot fulfill civil air navigation requirements related to the various phases of flight. The Federal Aviation Administration (FAA) is working on two major systems for augmenting (enhancing) GPS so that it can meet these requirements and become a primary means of navigation.

GPS, Alone, Does Not Meet Civil Air Navigation Requirements

GPS does not satisfy civil air navigation requirements, including availability, integrity, and in the case of precision approaches (see fn. 2) accuracy requirements.

The availability of a navigation aid is defined as the amount of time that the system is available for use. Availability requirements for the different phases of flight dictate for safety-related reasons that the system's signals be available more than 99.9 percent of the time. However, under the current GPS constellation of 21 operational satellites and 3 spares, satellites are available only 98 percent of the time. Through its augmentations to GPS, FAA plans to provide users with several satellite signals similar to those provided by GPS so that signals are available virtually all of the time.

The integrity of a navigation aid is defined as its ability to provide timely warnings to users about the system's malfunctions. Integrity requirements for the different phases of flight dictate that warnings be provided to users within seconds of a system's malfunction. However, GPS' integrity warnings can take 15 minutes or longer. Through its enhancements to GPS, FAA intends to provide timely integrity warnings to users so that they know when GPS or its enhancements are malfunctioning.

The accuracy of a navigation aid is defined as the difference between the true and measured position of an aircraft, the latter position as calculated by on-board-the-aircraft equipment. Accuracy requirements for precision approaches range from a few meters to under a meter. However, GPS, by itself, provides accuracies of about 100 meters.[1] Through its augmentation to GPS, FAA plans to provide accuracy corrections to users so that the system can support all types of precision approaches.

[1]GPS satellites have two signals. One signal provides information only to U.S. government-authorized users. The other signal provides similar information to all users. This information allows users to calculate the time and their speed and tridimensional position (latitude, longitude, and altitude). For national security reasons, the accuracy of the positioning information provided by the second signal to all users is currently degraded to at least 100 meters. When this signal is not degraded, its accuracy ranges from 21 to 53 meters.

GPS' Augmentations

FAA is working to develop and implement wide and local area augmentation systems for augmenting GPS.

Wide Area Augmentation System

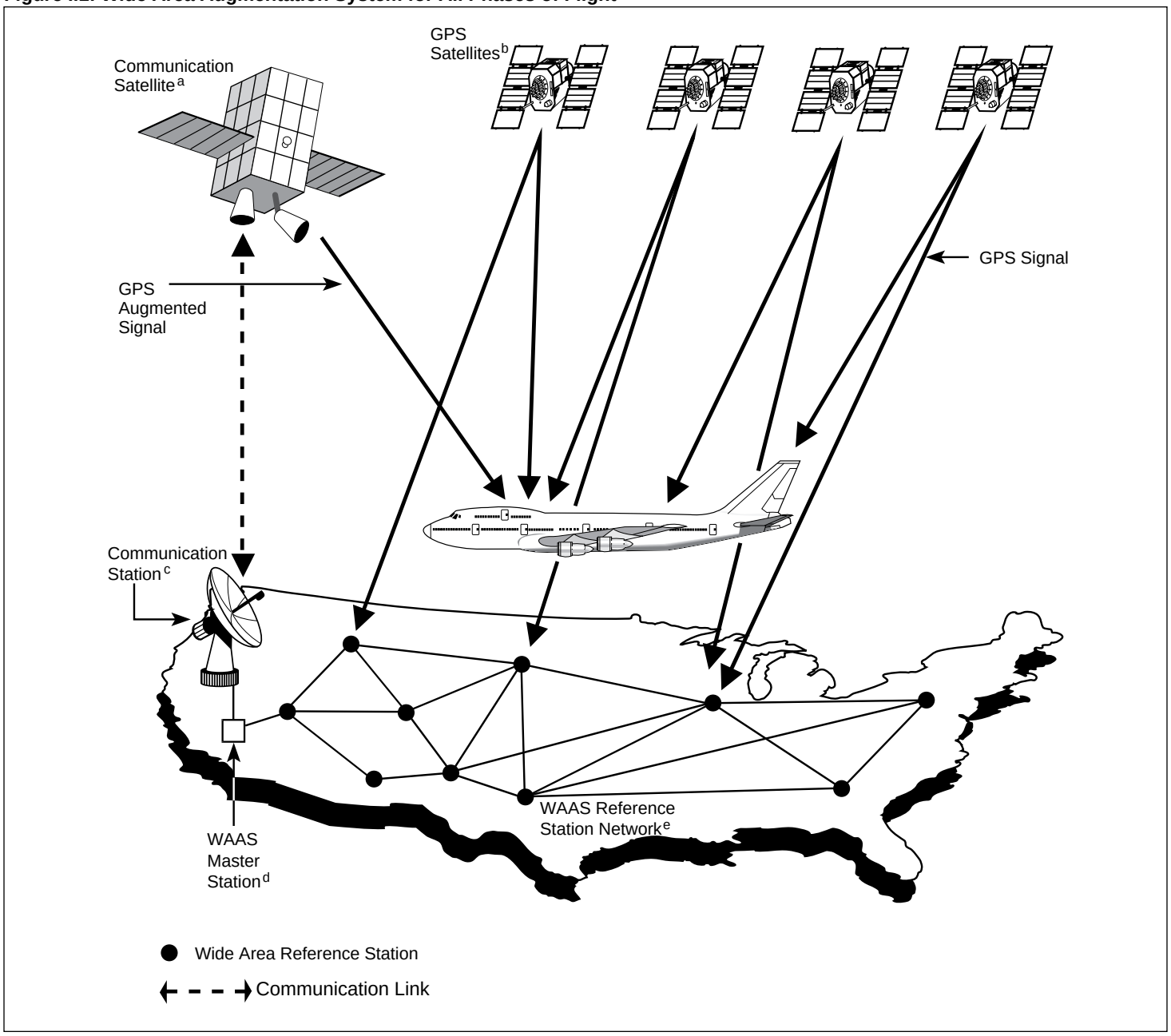
FAA is working on the development and implementation of a satellite-based wide area system that will permit GPS to satisfy the integrity, availability, and accuracy requirements needed to make it a primary means of navigation for supporting all phases of flight, including precision approaches.

FAA plans to use the wide area system to augment GPS in two phases. Under the first phase, FAA will use the system to enhance the availability and integrity of GPS. The system will transmit satellite signals similar to those provided by GPS, which will provide integrity warnings within 6 seconds of a malfunction. Under the second phase, FAA intends to enhance the accuracy of GPS for meeting the requirements of Category I precision approaches.[2] FAA recently received authorization to implement this accuracy enhancement.

The wide area system will have ground and space components for augmenting GPS. Figure I.1 depicts the wide area augmentation system.

[2]According to FAA, the wide area system will permit aircraft to rely solely on GPS for flying Category I precision approaches. Under a Category I approach, an aircraft receives guidance as it descends to a height of 200 feet above the ground when the runway's visibility is at least 1,800 feet. The system will not support Category II and III precision approaches, which are used by aircraft when they require greater navigational assistance under worse weather conditions. Under a Category II approach, an aircraft receives guidance as it descends to a height of 100 feet when the runway's visibility is at least 1,200 feet. Under a Category III approach, an aircraft receives guidance that permits it to descend and land when the runway's visibility is greatly reduced. Local area systems will be able to support Category II and III precision approaches.

Figure I.1: Wide Area Augmentation System for All Phases of Flight



Legend
WAAS = wide area augmentation system.

[a]Other communication satellites not shown.

[b]Other GPS satellites not shown.

[c]Other communication stations not shown.

[d]Other WAAS master stations not shown.

[e]Other WAAS reference stations not shown.

Source: Based on FAA's data.

The ground component will consist of a network of stations, including reference, master, and communication stations. Reference stations will, among other things, monitor the GPS satellite signals to generate integrity warnings and calculate corrections to improve the accuracy of the signals. Master stations will monitor the performance of the system, control reference stations, and process the integrity and accuracy information needed for augmenting GPS. Master stations, which will be located at several reference station sites, will send this information to communication stations. The latter will transmit the information to communication satellites—the space component—that in turn will broadcast the information to users with augmented signals similar to GPS signals. In addition to this operational wide area system, FAA plans to implement a smaller wide area system—called a functional verification system—to support related developmental, operational, and maintenance efforts.

FAA's strategy is to implement an initial wide area system by September 1997. The initial system, through a series of enhancements, is expected to become a final system by 2001. The initial system will consist of 2 master stations, 24 reference stations, and 6 communication stations. These stations will be joined by ground telecommunications. The system will use three communication satellites to deliver augmented signals similar to those provided by GPS to users. FAA envisions that the final system will consist of about 4 master stations, up to 40 reference stations, and up to 16 communication stations. The final system may use up to eight communication satellites. The functional verification system will consist of two master stations, five reference stations, and one communication station. It will require one communication satellite.

The initial system and the functional verification system will use the same software. This software will contain an estimated 150,000 lines of code. The final system's software may contain about 200,000 lines of code. This

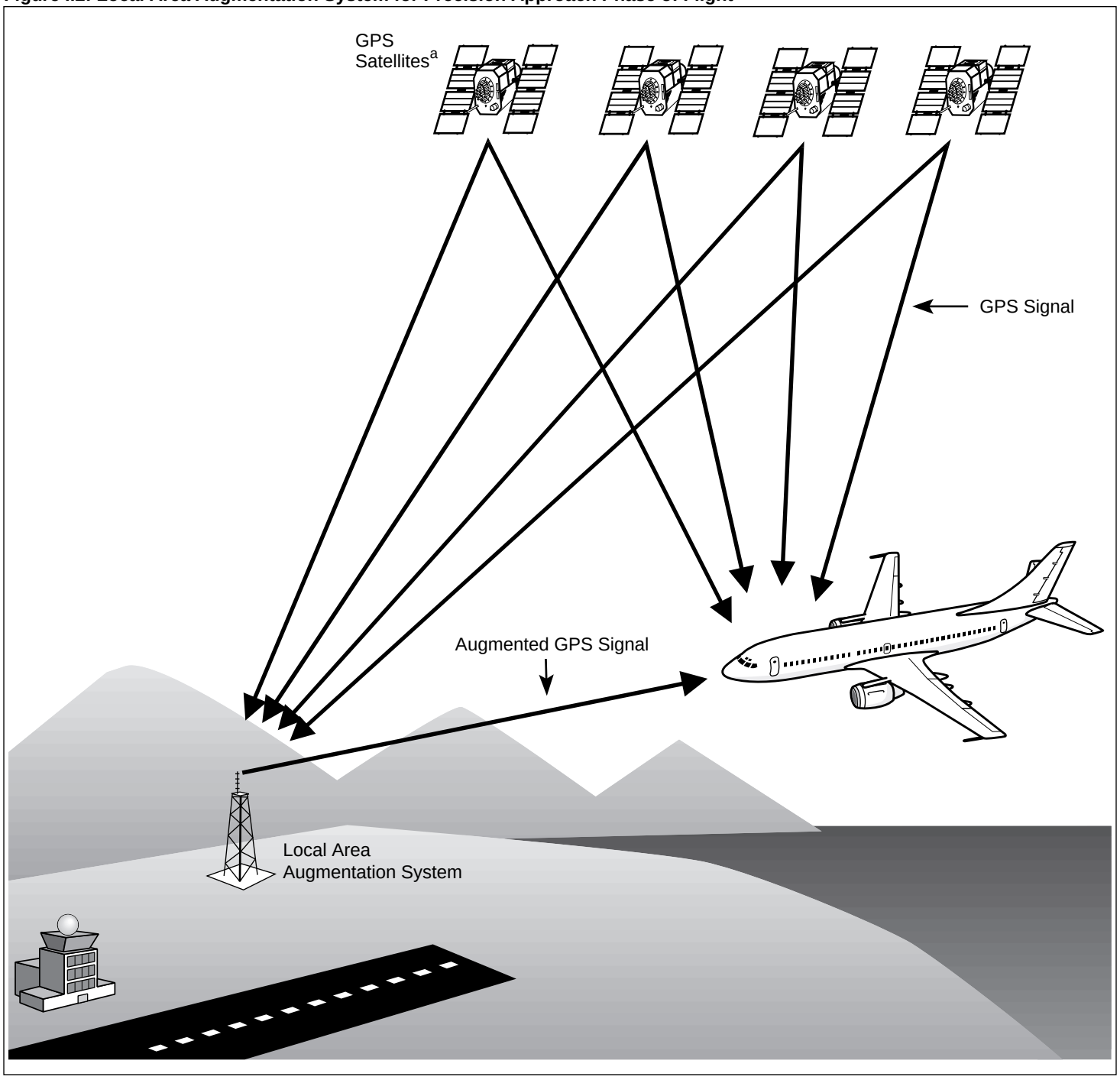
additional software code is intended to make the system capable of supporting Category I precision approaches and interfacing with other wide area augmentation systems implemented around the world.

To limit risks during the integration of the system and ensure proper interfaces between the system's components, FAA plans to award a contract for the wide area system to a single contractor. The contract will be a cost-plus contract because uncertainties affecting, for example, the software's development and integration do not permit FAA to estimate costs with the accuracy required for using a fixed-price contract. The contract will include incentives for the contractor to meet technical and cost goals. FAA expects to award the contract in May 1995. The contract, including four options, could extend for up to 8 years and will be funded incrementally.

Local Area Augmentation System

FAA is working on the development of a ground-based local area system that will allow GPS to satisfy the integrity, accuracy, and availability requirements needed to make it a primary means of navigation for supporting precision approaches. This local system uses a ground component for augmenting GPS. Figure I.2 depicts one of the systems under development. The ground component has one or more GPS monitoring stations located at known locations for detecting malfunctions and calculating accuracy corrections near or at the airport. After processing this information, the stations transmit it with an augmented signal similar to those provided by GPS to users.

Figure I.2: Local Area Augmentation System for Precision Approach Phase of Flight



[a]Other GPS satellites not shown.

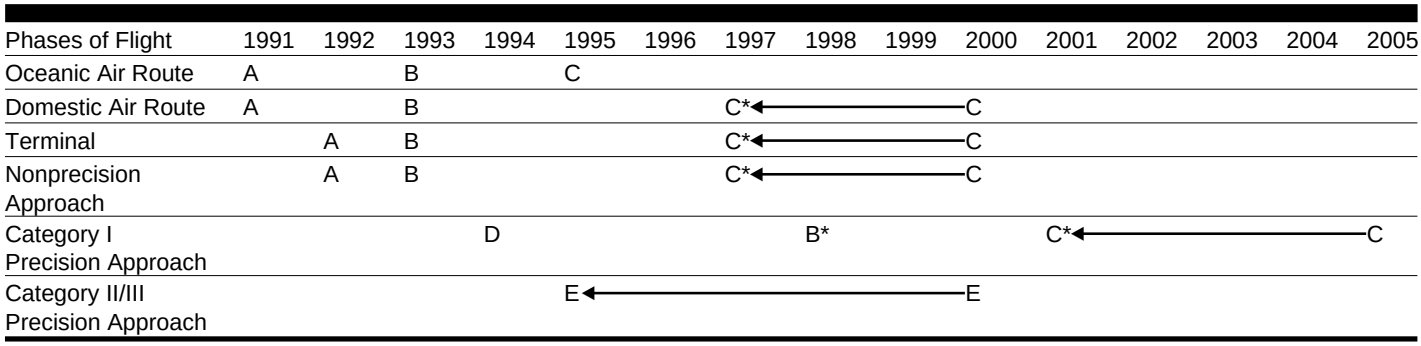
Source: Based on FAA's data.

Currently, FAA is sponsoring various efforts to develop local area systems to support all types of precision approaches. For example, in 1994, the agency awarded contracts to Wilcox Electric and E-Systems, at a cost of $1.67 million and $2 million, respectively, to develop and test demonstration systems using two different technologies.

FAA's Changes to GPS Milestones

Figure II.1 shows the milestones in the schedule for enhancing GPS. Also, it displays the extent to which FAA has accelerated some milestones since they were introduced in 1992. Future milestones in the schedule depend on the implementation of a wide area system for augmenting GPS nationwide by 1997.

Figure II.1: FAA's Fiscal Year Milestones for GPS



Legend

A: GPS for multisystem navigation. Under this mode, a pilot uses the system in conjunction with one or more commissioned air navigation aids for obtaining reliable information on the aircraft's position. The aircraft must carry equipment for both GPS and the navigation aids, and the pilot must constantly cross-check the GPS-derived positioning information with the other systems' information.

B: GPS augmented for supplemental navigation. Under this mode, the pilot uses the augmented GPS by itself for determining the aircraft's position. However, because the GPS signals may not be available during one of the phases of flight, the aircraft must carry equipment for a commissioned air navigation aid as a backup.

C: GPS augmented for primary means navigation. Under this mode, the pilot uses the augmented GPS by itself. However, the aircraft does not have to carry equipment for a commissioned air navigation aid as a backup.

B* and C*: Milestones based on the implementation of the wide area augmentation system.

D: GPS augmented for special Category I precision approaches. Under this mode, a pilot uses GPS augmented by privately owned local area systems for flying this type of precision approach.

E: Feasibility determination of GPS' augmentation for supporting Category II/III precision approaches. FAA determines whether GPS augmented by local area systems can support these types of precision approaches.

Source: Based on FAA's 1992, 1993, and 1994 development plans and 1994 implementation plan.

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