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NATIONAL AIRSPACE SYSTEM

Problems Plaguing the Wide Area Augmentation System and FAA's Actions to Address Them

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Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss the Federal Aviation Administration's Wide Area Augmentation System (WAAS)—a key effort under the agency's multibillion-dollar program to modernize the nation's air traffic control system. Today, FAA relies primarily on a ground-based navigation system to assist pilots in flying their assigned routes and to provide them with the guidance they need to safely land their aircraft in all kinds of weather. However, FAA's current navigation system is aging and limited in its geographic coverage. Therefore, FAA is planning a transition from its ground-based system to a new satellite-based navigation system using radio signals generated by the Global Positioning System (GPS). The Department of Defense developed GPS to support military missions and functions. However, the system is now a dual-use system, and other users—pilots, truckers, and boaters—rely on signals from the GPS satellites to calculate their time, speed, and position anywhere on or above the earth's surface. With its new navigation system,[1] FAA expects to improve the safety of flight operations, allow the fuel-efficient routing of aircraft, and eventually phase out most of its existing ground-based navigation aids.

FAA estimated that its future investment in the new navigation system could exceed $8 billion from 2000 through 2020. The cost of developing WAAS—the largest component of this system—has increased by over $500 million, primarily because of unanticipated development costs and additional program support costs. In addition, WAAS has been delayed for over 3 years and has experienced performance problems. As we have previously reported, FAA has historically experienced major difficulties in delivering modernization projects within cost, schedule, and performance parameters. The WAAS program has been no exception.

[1] We refer to the augmented satellite navigation system and its components—including the Local Area Augmentation System and existing ground-based navigation aids—as FAA's new navigation system. Also, throughout this statement, unless otherwise specified, costs are presented in "then-year-dollars," which are current dollars, inflated using Office of Management and Budget guidance.

My statement today—primarily based on a recently issued report[2]—will focus on (1) difficulties in developing WAAS, (2) actions FAA is taking to get the system on track, and (3) next steps for FAA to take to help mitigate future delays in implementing WAAS. In reviewing the WAAS program, we interviewed FAA officials, examined studies, and spoke with experts in aviation navigation and related technologies to obtain their views on the capability of FAA's new navigation system.

In summary:

- From very early on, FAA has underestimated the complexity of developing WAAS, which has led to cost increases and schedule delays. For example, in 1994, FAA estimated that it would cost $508 million to develop WAAS and promised to begin implementing the system by 1997. The agency did not deliver on this promise, in part because of an aggressive schedule, which proved difficult to meet when the agency ran into problems in developing the WAAS design. These problems, in turn, led to the need for more software development. FAA is again experiencing difficulties—mainly because of problems in meeting the system's key integrity requirement—that WAAS would virtually never fail to warn pilots of potentially hazardous misleading information. As a result, we estimate that the agency will not deliver on its initial promises until 2003 and may incur additional costs of between $200 million to $240 million. Even though FAA's analyses have shown the quantified benefits of WAAS outweigh the costs, problems with the integrity requirement make this conclusion less certain.

- To get the program back on track, FAA is taking a number of actions. First, consistent with federal legislation related to information technology investments, the agency is taking a more incremental approach and in doing so is abandoning its high-risk approach of combining different phases of system development in an effort to more quickly implement systems. The agency is also planning to develop

[2] See *National Airspace System: Persistent Problems in FAA's New Navigation System Highlight Need for Periodic Reevaluation* (GAO/RCED/AIMD-00-130, June 12, 2000).

"checkpoints" at which it will reevaluate WAAS development before making additional investments. Second, FAA is working more collaboratively with the aviation community—airlines, equipment manufacturers, and the Department of Defense—instead of making unilateral decisions about the WAAS design. Finally, to address the integrity problem, the agency is currently participating in a team effort with its contractors and consultants to recommend solutions that will prove the system's integrity performance by the end of 2000.

- While FAA's actions go a long way toward helping the agency implement WAAS, we believe that additional steps are necessary to ensure that FAA puts into place a framework to mitigate future delays and cost increases. To this end, as we recommended in our June 2000 report, FAA will need to develop a comprehensive plan that incorporates the future checkpoints for the agency's investment in its new navigation system. It will be critical for this plan to require FAA to revisit its investment if WAAS cannot perform as intended. Furthermore, to provide the Congress with assurances that the agency has addressed these problems, we also recommended that an external organization evaluate the agency's progress at established checkpoints. The result of this external evaluation should be included in FAA's request for future funding of the new navigation system. FAA generally agreed with our recommendations, and we expect the agency to implement them.

Background

In the 1980s, FAA decided to augment GPS with other navigational aids—WAAS and the Local Area Augmentation System (LAAS) to satisfy civil aviation requirements. However, at this time, civil aviation relies principally on a ground-based navigation system that uses various types of equipment to provide navigation and landing services to pilots in different types of weather. This equipment meets FAA's performance

requirements for accuracy, integrity, and availability;[3] however, it is aging and has limitations in its geographic coverage. Although the Department of Defense developed GPS to support military missions and functions, it is now a dual-use system that other users, such as pilots and boaters, rely on to calculate their time, speed, and position anywhere on or above the earth's surface.[4] Last month, in an effort to make GPS more useful to civilians, Defense ceased its practice of intentionally degrading the accuracy of the GPS signal available for civil use.[5] Even with the improvements in accuracy and other planned Defense improvements, GPS will not satisfy all civil aviation requirements for ensuring safe aircraft operations.

WAAS, a key FAA information technology project,[6] is being designed to provide the same level of service as today's ground-based equipment and is expected to support navigation through all phases of flight as well as nonprecision and category I precision landing approaches for a wider geographic area.[7] When fully developed, WAAS could comprise a network of up to 76 ground stations and three to four geostationary communications satellites. (See fig. 1 for an illustration of the WAAS operating system.) As part of its

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[3] FAA defines accuracy as the degree to which a navigation system calculates an aircraft's true position. Integrity is the ability of a navigation system to provide timely warnings when its signal is providing misleading information that could potentially create hazards for pilots and thus should not be used. Availability is the probability that a navigation system meets the accuracy and integrity requirements.

[4] The Department of Defense operates 24 orbiting GPS satellites to ensure a basic configuration of 24 working satellites at any given time for both military and civilian use. Replacement satellites will be launched as needed. These GPS satellites are positioned so that at any given time the signals from a minimum of four satellites will be available to users.

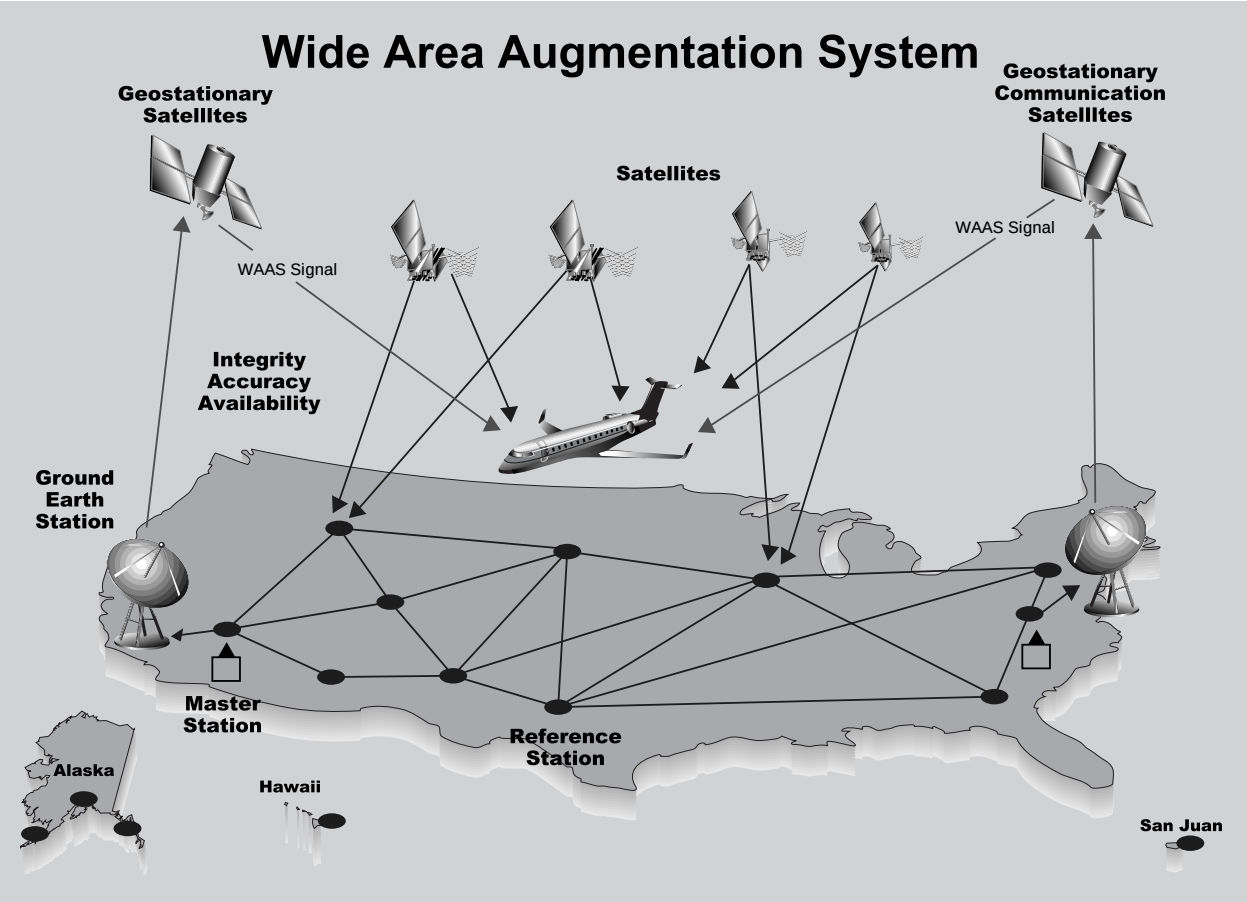
[5] In the past, the Department degraded the accuracy of the GPS signal using a process known as "selective availability."

[6] The air traffic control modernization effort includes over 50 information technology projects—the software-intensive and complex information and communication systems supporting the air traffic control system.

[7] Navigation guidance is provided to pilots through all phases of flight—at high altitudes and in areas close to airports. In a nonprecision approach, the pilot relies on instruments on board the aircraft to guide it safely from a height ranging from between 700 and 400 feet above touchdown. In contrast, in a category I precision approach, the pilot relies on instruments to provide an aircraft with safe vertical guidance to a height of not less than 200 feet above touchdown.

augmentation of GPS, FAA, in partnership with industry,[8] is also developing LAAS to support, among other things, even more stringent precision approach guidance than expected from WAAS.[9]

Figure 1: The Operating System for WAAS



Source: FAA.

Although FAA's original plans call for phasing out almost all of its ground-based navigation infrastructure, FAA now plans to retain about 30 percent of it ground-based

[8]Beginning is fiscal year 1999, FAA established a partnership with interested commercial entities for the purpose of developing LAAS. FAA expects this partnership to culminate in the development of a certified category I precision approach using LAAS by the end of fiscal year 2002.

[9] LAAS is expected to provide pilots with safe vertical instrument guidance to heights ranging from less than 200 feet to down to the runway surface. While LAAS is independent of WAAS, it is also expected to complement WAAS and provide precision approaches at airports where WAAS does not provide sufficient geographic coverage.

system to address concerns about the vulnerability of the GPS signal, which WAAS relies on, and to support those users who choose not to purchase the equipment that must be used with WAAS. Both WAAS and LAAS would require airlines and general aviation users to purchase on-board equipment for receiving signals from this new technology. These purchases are expected to occur over time, as the new navigation system is developed.

WAAS and LAAS are being developed under a single FAA integrated product team, which includes representatives from FAA's aircraft certification and acquisition organizations. FAA established integrated teams to help ensure that systems are developed and implemented in an efficient and effective manner. These teams are to be empowered to make decisions affecting systems and services, from their inception to their eventual disposal or termination. The effective operation of the integrated teams is key to FAA's goal of producing timely, cost-effective acquisitions.

FAA Underestimated the Complexity of Developing WAAS, Which Led to Program Delays and Cost Increases

FAA's effort to augment the GPS signal has run into problems similar to those that have plagued other modernization projects. For example, WAAS implementation was delayed by 3 years, in part because of the ambitious nature of the schedule—developing, testing, and deploying the system within 28 months. FAA is still experiencing development problems, which could delay the program by an additional 3 years. A common theme throughout FAA's system implementation efforts is the agency's tendency to underestimate the complexity of development tasks.

Aggressive Schedule Proved Difficult to Meet

In 1994, at the urging of government and aviation industry groups, FAA accelerated implementation of the WAAS milestones from 2000 to 1997, and it projected that it would begin providing initial capability for precision guidance (category 1 approaches) through

WAAS by June 1997.[10] In a 1995 report,[11] we expressed our concern that the accelerated schedule was ambitious and that potential problems could affect the system's development. In particular, we noted that FAA's commitment to an accelerated schedule was challenging because it would not provide enough time for the agency to complete all of the necessary steps to implement the system. This proved to be true when FAA ran into difficulties with its plan to implement the system in a 28-month period. From May 1995 through September 1997, FAA planned that the contractor would develop and implement the system, and the agency would accept and commission it. However, this schedule allowed little time for system acceptance and commissioning because software development alone was expected to take 24 to 28 months.

Delays Continue Because of Software Development and Integrity Issues

FAA is still having trouble meeting WAAS' implementation milestones—in part because of difficulties in developing software and proving the integrity requirement. Regarding software development, in January 1999, FAA slipped the schedule for the initial WAAS capability by 14 months—from July 1999 to September 2000—largely because of problems in developing the WAAS design, which led to the need for more software development. Given past problems and the complexity of the remaining development efforts, we believe that FAA will continue to experience delays. For example, FAA estimates that for WAAS to meet its full capability, the contractor will need to develop about 370,000 or more additional lines of code on top of the 350,000 already under development.[12] According to FAA, the additional lines of code will be needed to, among other things, provide for the security of the system and to expand its operating

[10] WAAS' initial capability was defined as vertical guidance of 200 feet above touchdown with a one-half to three-fourths mile visibility and a 19.2 meter vertical protection limit in which an aircraft can maneuver and still land safely. This capability was to be available 95 percent of the time to about 50 percent of the continental United States.

[11] See *National Airspace System: Comprehensive FAA Plan for Global Positioning System Is Needed* (GAO/RCED-95-26, May 10, 1995).

[12] Software size is usually measured in lines of code. A line of code is a set of instructions for the computer to perform a certain task and is one basis for estimating costs for items such as coding, analysis, design, and tests efforts required for producing the line of code.

capability. Software development—the most critical component of key FAA modernization programs—has been the Achilles' heel of FAA's efforts to deliver programs on time and within budget.[13]

As for the integrity issue, in December 1999, FAA found that the WAAS design could not be relied upon to satisfy the agency's requirement for system integrity for precision approaches. FAA's integrity requirement stipulates that WAAS cannot fail to warn pilots of misleading information that could potentially create hazardous situations more than once in 10 million approaches. Consequently, FAA has determined that it will not make its scheduled date of September 2000 to begin providing an initial capability for precision guidance through WAAS. The delay could have implications for FAA, system users, and equipment manufacturers. For example, FAA may need to buy new ground-based navigation equipment or maintain existing equipment longer than expected—maintaining existing equipment costs about $170 million annually, according to FAA. Likewise, system users and equipment manufacturers could question the wisdom of making further investments in WAAS technology. Because of these implications, FAA, with users' support, has decided to provide only a limited precision guidance capability with WAAS by 2002.[14] FAA has yet to determine when WAAS will achieve its initial capability. Using information provided by FAA and its experts, we estimate that resolving the integrity problem could potentially delay making WAAS' initial capability available by 3 years or more and add approximately $200 million to $240 million to the cost of developing WAAS. (See app. I for more changes to WAAS development cost, schedules, and requirements for precision approaches.)

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[13] See *Air Traffic Control: Immature Software Acquisition Processes Increase FAA System Acquisition Risks* (GAO/AIMD-97-47, Mar. 21, 1997).

[14] By 2002, FAA plans to provide vertical guidance of 350 feet above touchdown with 1-mile visibility and a 50 meter vertical protection limit in which an aircraft can maneuver and still land safely. This capability is to be available 95 percent of the time to about 75 percent of the continental United States.

The difficulties in proving the integrity requirement have occurred largely because

- FAA management and the integrated product team underestimated the complexity of resolving the integrity issue—failing to recognize the seriousness of the problem.

- FAA did not closely monitor the contractor's effort to demonstrate integrity. Although a WAAS study group informed FAA that it would be difficult to prove WAAS' stringent requirements in October 1997, it was nearly 2 years later, in September 1999, when the aircraft certification members of the integrated product team became actively involved and the agency fully understood the difficulty in proving the requirement. Furthermore, the contractor did not deliver detailed plans for addressing the integrity issue in a timely manner.

- Integrated product team members did not have a clear understanding of their roles; consequently, members did not effectively communicate with each other and the contractor.

FAA officials acknowledged that it should have paid attention to the integrity issue sooner and offered these reasons for the delay: (1) competing priorities between organizations on the integrated product team hindered the team's approach to meeting the agency's WAAS goals;[15] (2) a shortage of in-house technical expertise and the team's attention to other important issues, such as system design; and (3) the lack of a sufficiently defined agency process for identifying and conveying to the contractor the results that would be acceptable for proving WAAS' integrity. The lack of monitoring and poor communications have been recurring problems in FAA's air traffic control modernization program. For example, in 1996, we reported that inadequate oversight of

[15] According to FAA's senior management, this situation may have developed because FAA's aircraft certification organization is more accustomed to being involved after a project is developed, rather than actively participating throughout its development. As we reported in 1996, FAA's product teams have not always forged true partnerships across organizational "stovepipes." See *Aviation Acquisition: A Comprehensive Strategy is Needed for Cultural Change at FAA* (GAO/RCED-96-159, Aug. 22, 1996).

contractors' performance was a major contributor to FAA's recurring cost, schedule, and performance problems with other projects in the modernization program.[16]

Actions FAA Is Taking to Help Ensure WAAS Success

To get the WAAS program on track, the agency is taking a number of steps. First, FAA has decided to take a more incremental approach to implementing the new navigation system—focusing more on the successful completion of research and development before starting system deployment. In doing this, the agency is attempting to build discipline into the acquisition management process. This action is consistent with a key goal of the Clinger-Cohen Act, which encourages agencies to have processes and information in place to help ensure that information technology projects are being implemented at acceptable costs and within reasonable and expected time frames and are contributing to tangible, observable, improvements in mission performance. Second, FAA is working on a continuing basis with system users to ensure that their needs are understood and considered during system development. Finally, the agency has established a team consisting of FAA officials, its contractors, and consultants to find solutions to the system's integrity problems.

FAA Is Taking a More Incremental Approach to WAAS Development

FAA acknowledges that the manner in which it decided to implement WAAS development was a high-risk approach and was the primary issue underlying the system's problems. According to FAA, the agency agreed on a system design and set milestones for system deployment before completing the research and development required to prove the system's capability. As we have reported for other FAA modernization projects, when the agency attempts to combine different phases of system development in an effort to more quickly implement systems, it repeatedly experiences

[16] See *Aviation Acquisition: A Comprehensive Strategy is Needed for Cultural Change at FAA* (GAO/RCED-96-159, Aug. 22, 1996).

major performance shortfalls, which lead to delays and additional costs.[17]

Recognizing the problem, FAA is in the process of implementing a new approach to developing WAAS. Under this approach, before making additional investments, FAA has indicated that it plans to allow time for collecting and evaluating data on (1) system performance, (2) the extent to which users have purchased equipment, and (3) the availability of emerging new technologies for the new navigation system. In essence, FAA plans to reevaluate WAAS at critical "checkpoints" in its development.

FAA Is Working Collaboratively With System Users

To FAA's credit, it has been working collaboratively with aviation users and industry groups since at least early 1999 to discuss alternative approaches to the new navigation system and ways to make a smooth transition from the existing to the new system. For example, the Satellite Navigation Users Group—which includes representatives from commercial, general aviation, and Department of Defense users—was created to achieve consensus throughout the user community and within FAA for making the transition to the new navigation system. FAA has held a number of meetings with this group as well as other users to seek their input and support. For example, in March 2000, FAA held a satellite navigation summit to update users on WAAS' performance concerns and to obtain users' buy-in on revised system deliverables. It was in this forum that the Satellite Navigation Users Group reaffirmed its support for WAAS. This new approach represents a change from the past, when FAA tended to make decisions unilaterally, without user input.

[17] *See Air Traffic Control: Observations on FAA's Air Traffic Control Modernization Program* (GAO/T-RCED/AIMD-99-137, Mar. 25, 1999).

FAA Has Established a Team of Satellite Navigation Specialists to Resolve WAAS' Integrity Problems

To resolve WAAS' integrity problems, FAA has established a team of satellite navigation specialists known as the WAAS Integrity Performance Panel. This team, which includes representatives from FAA, the Mitre Corporation, Stanford University, Ohio University, and the Jet Propulsion Laboratory, was created to improve the calculations for better identifying potentially hazardous information—thereby proving the system's integrity performance. While the team is not expected to complete all of its work until the end of 2000, it expects to have preliminary results by July. This should enable FAA to continue system development so that limited operating capabilities can be provided in calendar year 2002. Furthermore, according to an FAA official, the agency has established an Independent Review Board, which is independent of the panel and includes experts in satellite navigation, safety certification, and radio spectrum policy, to oversee the panel and the soundness of its efforts.

Next Steps to Help Mitigate Future Delays in Implementing WAAS

While the actions that FAA has undertaken have the potential to address the current problems, additional steps are needed to help mitigate future delays in implementing WAAS. For example, a comprehensive plan to implement WAAS and progress reports would provide FAA, users, and the Congress with a mechanism to monitor progress. In addition, senior management support for the integrated product team concept is critical to help ensure the successful implementation of future modernization projects while avoiding the pitfalls experienced by WAAS.

FAA Needs a More Concrete Implementation Plan, and the Congress Needs WAAS Progress Reports to Make Funding Decisions

In the past, FAA has undertaken initiatives without paying attention to factors critical to achieving the desired results, such as an evaluation plan to measure progress. We see a

potential for repetition of this pattern. For example, FAA talks about establishing checkpoints to ensure progress and the appropriate use of funds, but it has not developed a detailed plan explaining when these checkpoints would occur, what they would accomplish, who would be responsible for overseeing them, and how progress would be measured. Therefore, in our June 2000 report,[18] we recommended that FAA develop a comprehensive plan to provide the framework for the agency's future investments in its new navigation system. Furthermore, our past reviews of FAA's efforts to develop systems show that the agency does not always inform the Congress in a timely fashion of problems it is encountering before requesting additional funds. To this end, we recommended that an external organization evaluate the agency's progress at these checkpoints and include the results of this evaluation in the agency's request for future funding of the new navigation system. FAA generally agreed with our recommendations, and we expect the agency to implement them.

FAA Senior Management Needs to Fully Support the Integrated Product Team Concept

A key role of the integrated product team is to help ensure the efficient and effective development and implementation of FAA systems through cross-functional agency interaction. However, the lack of attention by FAA's senior management to ensuring that the team was functioning properly appears to be a major reason it has not worked as intended for WAAS. To this end, we believe that program success will only come about if senior FAA management embraces and fully supports the integrated product team concept. Otherwise, more projects may experience the same problems WAAS has encountered. For WAAS, senior management will need to establish an on-going process for the team to reach consensus on how the contractor must demonstrate that a project meets the agency's performance requirements and to convey this information to the contractor.

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[18] See *National Airspace System: Persistent Problems in FAA's New Navigation System Highlight Need for Periodic Reevaluation* (GAO/RCED/AIMD-00-130, June 12, 2000).

Mr. Chairman, this concludes my statement. I will be happy to answer any questions that you or Members of the Subcommittee may have.

Contacts and Acknowledgments

For future contacts regarding this testimony, please contact Gerald L. Dillingham at (202) 512-2834. Individuals making key contributions to this testimony include Jennifer Clayborne, Pete Maristch, Belva Martin, and John Noto.

Appendix I

Changes to WAAS Development Costs, Schedules, and Requirements for Precision Approaches, June 1994 Through June 2000

Dollars in millions

Year	Estimated development costs	Initial capability	Requirement for precision approaches	Full capability	Requirement for precision approaches
1994	$508	6/97	Precision approach capability was for a 19.2 meter Vertical Protection Limit, with 95% availability, throughout 50% of the continental U.S. In the best case, this would provide Category I precision approach minimums (200 feet height above touchdown and ¾ mile visibility, ½ mile with approach lights).	12/00	Precision approach capability was for a 19.2 meter Vertical Protection Limit, with 99.9% availability, throughout 100% of the total National Airspace System. In the best case, this would provide Category I precision approach minimums (200 feet height above touchdown and ¾ mile visibility, ½ mile with approach lights).
1/98	$1,007[a]	7/99	Same as June 1994	12/01	Same as June 1994
1/99	$1,007	9/00	Same as June 1994	To be determined	Same as June 1994
9/99	$2,484[b]	9/00	Same as June 1994	12/06	Same as June 1994
6/00	$2,724[c]	12/02	Limited precision approach capability to 50 meters Vertical Protection Limit, with 95% availability, throughout 75% of the continental US. In the best case, this would provide vertically guided approach to at around a 350 feet height above touchdown and 1 mile visibility.	To be determined	To be determined

Note: Since 1996, FAA has been including life-cycle costs, which include costs for developing, operating, and maintaining projects. The current life-cycle cost estimate for WAAS is about $3.2 million.

[a] The Jan. 1998 program development costs for WAAS include the prime contractor costs, development of standards and procedures, technical engineering and program support, and the first year of costs for satellites. A primary reason for the cost growth between June 1994 and January 1998 was due to unanticipated development costs to build greater reliability into the WAAS ground component.

[b] The Sept. 1999 estimate for WAAS development includes $1.3 billion in satellite service acquisition through 2020. In earlier estimates, satellite service acquisition costs were included in the cost of operating WAAS.

[c] GAO estimated the increase between the Sept. 1999 and June 2000 on the basis of information provided by FAA and its experts. We estimate that to meet the June 1994 performance expectation for initial WAAS could add up to $240 million to the cost of developing WAAS and potentially take 3 years or more beyond Sept. 2000.

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