



United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division



B-276928

August 7, 1997

Congressional Requesters

Subject: National Airspace System: Questions Concerning FAA's Wide Area Augmentation System

The Federal Aviation Administration (FAA) is planning a transition to satellite-based navigation guidance, using satellite signals generated by the Department of Defense's Global Positioning System (GPS). The GPS network of 24 satellites transmits 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. However, as currently designed for military purposes, GPS does not satisfy civil aviation requirements. FAA is developing a Wide Area Augmentation System (WAAS) to enhance GPS by correcting signal errors, increasing satellite coverage, and providing timely warnings to users of system malfunctions.

FAA expects to use GPS, when augmented, to replace a variety of costly ground-based navigation systems that were built on technologies dating back to the 1950s and before. Satellite-based navigation will improve the safety of flight operations, allow fuel-efficient routing, and increase airport and airspace capacity to meet future air traffic demands.

The basic concept and operational feasibility of WAAS has been demonstrated, and a contract for the development of the operational system was awarded to Wilcox Electric in August 1995. Because of concerns about the contractor's performance, FAA terminated the contract in April 1996 and in May 1996 entered into an interim contract with Hughes Aircraft. The interim contract with Hughes was subsequently expanded and finalized in October 1996. The final \$483.5 million contract provides for a three-phase development effort. Development costs are estimated to be \$220.9 million for Phase 1, \$94.1 million for Phase 2, and \$168.5 million for Phase 3 of the contract.

GAO/RCED-97-219R FAA's Wide Area Augmentation System

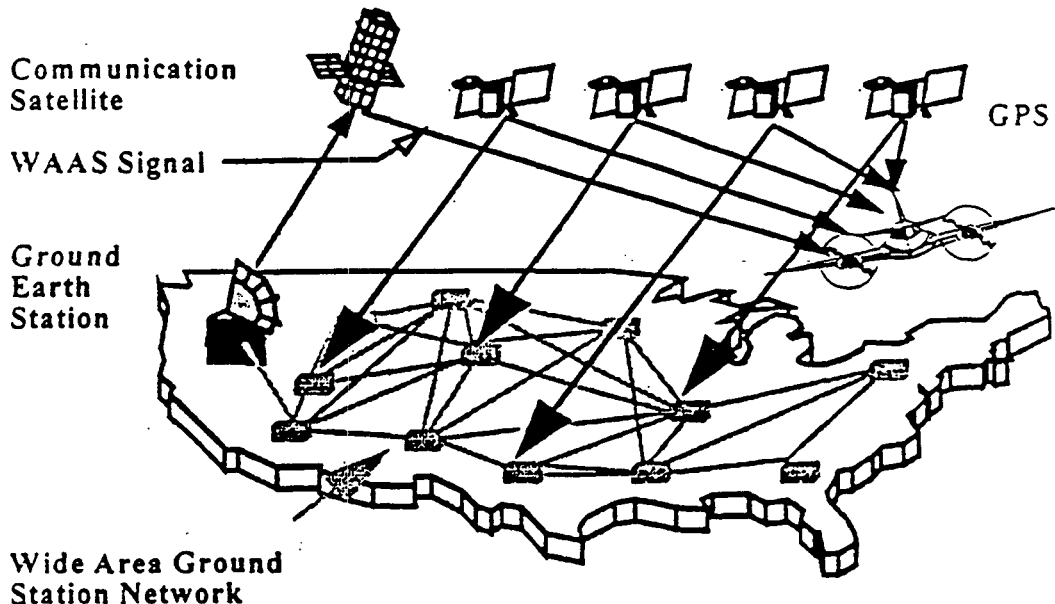
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Concerned about the cost of WAAS' development and FAA's replacement of the contractor, you asked us to respond to the following questions: (1) What is the history of WAAS cost estimates and major factors in cost changes? (2) What is the history of WAAS program requirement changes and sources for these changes? (3) What were the factors in FAA's decision to terminate the Wilcox contract? (4) What would be the implications of ending WAAS' development at the completion of Phase 1? We briefed your staff on these issues during the week of July 7, 1997 (see enc. D).

BACKGROUND

WAAS is a single system comprised of a network of ground stations and communications satellites. The ground stations will receive and monitor the GPS signals. The integrity and accuracy of the signal data will be assessed, and integrity warnings and satellite corrections will then be transmitted to aircraft via communications satellites. The satellites will also serve as additional sources of GPS signals to provide greater coverage for all aircraft. (See fig. 1.)

Figure 1: WAAS Architecture



Source: Federal Aviation Administration.

Under the Hughes contract, the system was scheduled to reach an initial operational capability (Phase 1 WAAS) in December 1998. FAA expects this schedule to be delayed, however, because of engineering change proposals that

are pending approval. Phase 1 WAAS will be able to support the navigation of planes for all phases of flight through Category I precision approaches.¹ But it will not have the back-up capability to continue operations in the event of equipment failures and will have to be backed up by FAA's current ground-based system.

To make WAAS capable of serving as FAA's only system for air navigation guidance, the agency plans to expand the system in Phases 2 and 3 of the contract. Phase 3 is scheduled for completion by 2001. FAA intends to use options in the WAAS contract for increasing the number of ground stations and also plans to acquire or lease additional communications satellites. The agency expects to phase out its old ground-based systems for navigation guidance over a period of approximately 5 years, beginning in 2005.

HISTORY OF WAAS COSTS

According to FAA, the estimated facilities and equipment (F&E) cost of the WAAS program grew from \$507.9 million in December 1994 to \$957.4 million in April 1997—a cost growth of over \$400 million, or almost 90 percent. The major factors responsible for the estimated cost growth were increases of (1) over \$200 million in unanticipated development costs to build greater reliability into WAAS' ground component to help ensure that the system will be available even in the event of equipment failures, (2) \$77 million for additional program support for FAA's oversight of the program and the WAAS contractor, (3) \$75 million for work performed by Wilcox and the estimated settlement costs of terminating the contract, and (4) \$65 million for satellite upgrades and improvements recommended by the White House Commission on Aviation Safety and Security (Gore Commission).² The Gore Commission recommended developing an additional radio frequency on the next generation of GPS satellites and adding GPS-like signals to existing communications satellites.

¹FAA categorizes the approach and landing of an aircraft according to the aircraft's height above touchdown and range of visibility. A Category I precision approach is one in which an aircraft receives guidance as it descends to a height of 200 feet or higher when the runway's visibility is at least 1,800 feet.

²The Gore Commission, established by President Clinton, issued a report in February 1997 that made over 30 recommendations concerning aviation safety, security, and air traffic control.

As discussed above, FAA attributes a significant portion of WAAS' cost growth to unanticipated development costs. These additional development costs would not be viewed as increases if FAA had used a range of high and low estimates to project program costs in December 1994. By using ranges, FAA could have conveyed the level of uncertainty that existed in the program cost estimates because WAAS was in its early stages of development.³

In addition to the F&E costs, FAA's December 1994 estimate included \$96.4 million in operations and maintenance (O&M) costs for communications—bringing total program costs to \$604.3 million. Although FAA's April 1997 estimate reduced O&M costs for communications to \$65.4 million because of lower expected costs for satellite communications, higher F&E estimates pushed total program costs to \$1.02 billion. Neither the December 1994 nor the April 1997 estimate included the \$2 billion in O&M costs now projected for the life cycle of the system.

In May 1997, FAA proposed a change to the WAAS cost estimate that would reduce estimated total costs from \$1.02 billion to \$842.1 million. This proposal would transfer \$50.3 million of F&E costs for satellite communications to a separate budget line item for communications, navigation, and surveillance. FAA believes that transferring funds to a separate line item will encourage other FAA projects that use communications satellites to share the F&E costs of these satellites. The proposal would also eliminate \$65 million of satellite improvements recommended by the Gore Commission because (1) a second radio frequency was not identified in time to be included in the next group of GPS satellites and (2) FAA has not made its requirements for the WAAS communications satellites final. Furthermore, because the May 1997 estimate reflects only F&E costs, it does not include the \$65.4 million in O&M costs for communications services that were previously included in the program's cost estimate.

HISTORY AND SOURCES OF CHANGES IN WAAS REQUIREMENTS

The final system that is to be delivered in 2001 under the Hughes contract will be fundamentally the same system that FAA originally contracted for with Wilcox, with no degradation in air navigation service or safety. However, to

³See discussion on the use of cost ranges in Air Traffic Control: Improved Cost Information Needed to Make Billion Dollar Modernization Investment Decisions (GAO/AIMD-97-20, Jan. 22, 1997).

hold down the costs of WAAS, the agency decided to assume responsibility for acquiring communications satellites and integrating these services with the ground component of WAAS—a role formerly assumed by Wilcox. FAA estimates that it will save \$11 million by contracting directly for these satellites. The contract periods of the Wilcox and Hughes contracts are also essentially the same, with some differences in the phasing of development activities. The system that was to be developed in two phases under the Wilcox contract will now be developed in three phases, with some operations and maintenance requirements deferred from Phase 1 to Phase 2. According to the systems engineering team leader of FAA's WAAS program, requirements were deferred to Phase 2 to even out the contractor's workload. However, because of delays caused by the termination of the Wilcox contract, the schedules for an initial WAAS operational capability and a final system were extended by about a year.

Some technical requirements changed when FAA made the transition from the Wilcox to the Hughes contract; however, these revisions are not expected to affect the final operational capability of WAAS. These changes included (1) stating certain requirements as goals in the interim contract and subsequently reestablishing them as requirements in the final contract and (2) revising some requirements that were originally set too conservatively or were not cost-effective. For example, the precision approach requirement for the Phase 1 effort was stated as a goal in the interim Hughes contract to conserve funds and because FAA expected that there would be no equipment on board aircraft capable of supporting WAAS precision approaches by 1998. These requirements were later restored on the basis of a reassessment of program funding and risks and discussions with the FAA Satellite Operational Implementation Team about the likely availability of onboard equipment by 1998. Other revisions include allowing more interruptions in the WAAS signal during Phase 1 because the requirement was originally set too conservatively and deleting the requirement for equipment status monitors at remote WAAS locations to reduce costs.

FACTORS IN FAA'S DECISION TO TERMINATE THE WILCOX CONTRACT

FAA terminated the Wilcox contract because the contractor did not provide effective project management. FAA identified the following factors as indicators of the contractor's poor management of the WAAS project: (1) inadequate staffing of the contract, (2) failure to award key subcontracts as scheduled, (3) probable cost overruns of at least \$100 million and schedule delays, (4) failure to meet contract milestones for system design review and

delivery of cost and schedule baselines, and (5) inadequate cost and schedule reporting.

IMPLICATIONS OF ENDING WAAS DEVELOPMENT
AT THE COMPLETION OF PHASE 1

Ending the development of WAAS after its initial operating capability is delivered at the end of Phase 1 would have programmatic and operational consequences with financial implications for FAA. From a programmatic standpoint, FAA would not save the entire \$262.6 million cost of Phases 2 and 3 of the WAAS contract because approximately \$75 million of this amount must be spent on activities involving hardware and software to support the Phase 1 system. Outside of the contract, FAA will need to spend \$32 million to lease communications satellites and \$40 million to develop GPS landing procedures and other guidance for implementing a GPS-based navigation system to support Phase 1 of WAAS. If the development of WAAS is ended at Phase 1, FAA may jeopardize existing and future agreements with U.S. border countries to contribute ground stations to the WAAS architecture, which would increase the number of stations that FAA would ultimately have to provide and fund.

Ending the development of WAAS at the completion of Phase 1 would also have operational implications. First, at the end of Phase 1, WAAS would not have the capabilities to serve independently as an air navigation system. As a result, it could not replace the current system of navigation aids, and FAA would incur O&M costs for operating two navigation systems. According to FAA, over a 20-year period, O&M expenses would total approximately \$4.2 billion for the present system and \$2 billion for a Phase 1 WAAS. FAA would also incur F&E costs to replace aging ground-based navigation aids. Second, stopping WAAS' development would have an impact on FAA's transition to a new air traffic management system, which is built on more direct routing of aircraft. According to FAA's National Airspace System architecture, satellite-based navigation (made possible by WAAS) is one of the key capabilities required for this transition. Therefore, many of the benefits associated with the new air traffic management system, such as the fuel-efficient routing of aircraft and an increased airspace capacity, may not be fully realized if WAAS does not become the sole source of navigation guidance. Finally, the safety benefits of having WAAS landing signals at airports that currently have no such capability may not be fully realized.

OBSERVATIONS

Several concerns about how FAA reports program costs and sets performance requirements came to light during our review of this project. With respect to cost reporting, because FAA presents WAAS' cost estimates as firm, discrete point estimates, FAA is implying a level of precision that cannot be supported, particularly in light of the uncertainties existing early in the system's development cycle. Fully disclosing the range of imprecision and uncertainty in the WAAS program estimates would increase the value of these estimates to investment decisionmakers in the Congress and at FAA. In addition, we are concerned that reporting the \$50.3 million in F&E costs for WAAS communications satellites in a budget line item that is distinct and separate from the WAAS program will make it difficult for decisionmakers to readily identify the full cost of the WAAS acquisition. Because satellite communications is a key component of WAAS, we question FAA's rationale for distinguishing these costs from WAAS program requirements in the agency's budget.

With respect to the WAAS performance requirements, we noted that some contract requirements have been set at higher levels than those needed to meet FAA's operational requirements. As a result, any changes that lower system requirements after the contract was awarded give the appearance that the requirements are being compromised, when in reality no degradation of air navigation service or safety is expected. For example, one requirement establishing the level of continuity for WAAS' correction signal exceeded the level needed to meet FAA's performance standards for Phase 1. This requirement was later revised on the basis of the FAA Satellite Operational Implementation Team's recommendations. FAA's lowering of the requirement also raises the question of whether setting system requirements too conservatively has cost implications, especially when a higher level of requirements increases the technical difficulty and engineering effort required to meet performance standards.

SCOPE AND METHODOLOGY

To develop information on cost changes, we reviewed the WAAS cost estimates presented by FAA in congressional briefings and the agency's draft request for a change in the WAAS baseline. However, we did not validate these estimates or examine the integrity of FAA's cost-estimating process. Regarding differences in contract requirements, we reviewed the Wilcox and Hughes contracts, contract modifications, and summaries FAA prepared. In addition, we obtained FAA's correspondence with Wilcox delineating the contractor's deficiencies and

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all documents supporting the agency's decision to terminate the Wilcox contract. Regarding the implications of ending the development of WAAS at the completion of Phase 1, we reviewed FAA's plans for decommissioning the current ground navigation aids and the costs associated with maintaining these systems. We also reviewed the activities and costs associated with Phases 2 and 3 of WAAS' development, FAA's implementation of WAAS, and FAA's plans for using GPS to support its National Airspace System architecture and more fuel-efficient routing. We performed our review during July 1997 in accordance with generally accepted government auditing standards.

AGENCY COMMENTS AND OUR EVALUATION

We received oral comments on a draft of this report from officials of the Department of Transportation and FAA, including FAA's Acting Director of the Office of Communication, Navigation, and Surveillance Systems and the Deputy Program Manager of the GPS Integrated Product Team. These officials expressed general agreement with the findings of the report and provided clarifying and technical suggestions, which we incorporated as appropriate.

We will send copies of the report to interested congressional committees, the Secretary of Transportation, and the Administrator of FAA. We will also make copies available to others on request.

If you or your staff have any questions or need additional information, please call me at (202) 512-3650. Major contributors to this report were Robert Levin, Debra Ritt, Peter Espada, Greg Carroll, and David Hooper.



Gerald L. Dillingham, Ph.D.
Associate Director, Transportation Issues

Enclosure

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List of Requesters

The Honorable Richard C. Shelby
Chairman

The Honorable Frank Lautenberg
Ranking Minority Member
Subcommittee on Transportation
Committee on Appropriations
United States Senate

The Honorable Slade Gorton
Chairman

The Honorable Wendell H. Ford
Ranking Minority Member
Subcommittee on Aviation
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable John J. Duncan, Jr.
Chairman

The Honorable William O. Lipinski
Ranking Minority Member
Subcommittee on Aviation
Committee on Transportation and Infrastructure
House of Representatives

GAO Resources, Community, and Economic
Development Division

FAA's Wide Area Augmentation of the Global Positioning System

Briefing for Congressional Requesters

GAO Questions for GAO Assessment of
WAAS

- What is the history of WAAS cost estimates and major factors in cost changes?
- What is the history of WAAS program requirement changes and sources for these changes?

GAO Questions for GAO Assessment of
WAAS

- What were the factors in FAA's decision to terminate the Wilcox contract?
- What would be the implications of ending WAAS development at the completion of Phase 1?

GAO WAAS Cost Estimates (in millions of dollars)

	Dec. 1994	May 1996	April 1997	May 1997 ^a
WAAS development	\$228.8	\$341.2	\$483.5	\$483.5 ^b
Communications (F&E)	84.0	N/A	59.8	9.5 ^c
Program support	42.4	83.1	118.9	118.9
NAS implementation	152.7	143.3	155.2	155.2
Wilcox sunk/ termination costs	N/A	N/A	75.0	75.0
Gore Commission recommendations	N/A	N/A	65.0	0 ^d
Total F&E	507.9	567.6	957.4	842.1
Communications (O&M)	96.4	129.3	65.4	0 ^e
Total program	\$604.3	\$696.9	\$1,022.8	\$842.1

^aFrom FAA's Financial Baseline Change Notice; not approved by Joint Resources Council.

^bRecent engineering changes could increase contract costs.

^c\$50.3 million of F&E associated with communications, navigation, and surveillance satellite communications will be a separate budget line item.

^dGore Commission changes regarding the second civil frequency and dedicated satellite upgrades were dropped.

^eDoes not include \$2 billion in O&M costs for 20-year period.

GAO WAAS Cost History

- April 1997 estimate projects total WAAS costs to be over \$1 billion--a growth of \$418.5 million since the 1994 estimate.
 - May 1997 estimate reduces WAAS program costs to \$842 million.
 - Reduction caused by removal of Gore Commission changes and communications costs.
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**GAO Major Factors in Cost Changes
(Dec. 1994 to April 1997)**

- Over \$200 million increase in WAAS development to build in greater redundancy in architecture
 - \$77 million increase in program support because of underestimated costs
 - \$75 million increase from sunk costs and terminating Wilcox contract
 - \$65 million increase to implement Gore Commission recommendations
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GAO Major Revisions to WAAS Requirements

- Final system is expected to be fundamentally the same as one that was originally proposed.
 - Contract periods for Wilcox and Hughes are essentially the same, but current WAAS schedule extended a year largely because of Wilcox termination.
 - Some changes have occurred, but with no impact on the system's operational capability.
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GAO Major Revisions to WAAS Requirements

Contract provision	Wilcox contract	Changes in Hughes contract
Uplinks and communications satellites	Wilcox would provide capability through subcontractor	Government would provide capability to reduce costs
WAAS development phases	Two phases: Initial WAAS (IWAAS) completed by end of 1998 and end-state WAAS (EWAAS) completed by 2001	Three phases: IWAAS becomes Phase 1; operations and maintenance requirements, previously under IWAAS, moved to newly created Phase 2 to even out workload during 1999-2000; EWAAS becomes Phase 3

GAO Major Revisions to WAAS Requirements

Contract provision	Wilcox contract	Changes in Hughes contract
Phase 1 precision approach capability	Requirement	Made goal in interim contract because avionics might not be available by 1998, but later restored to requirement in final contract
Average time to repair and restart system after outages	Requirement	Made goal in Hughes interim contract based on Wilcox experience, but later restored to requirement in final contract
Probability for WAAS signal continuity through nonprecision approaches for IWAAS/Phases 1 and 2	Requirement	Lowered in Hughes interim contract at Satellite Operational Implementation Team recommendation, but later restored to a requirement in final contract

GAO Major Revisions to WAAS Requirements

Contract provision	Wilcox contract	Changes in Hughes contract
Equipment status indicators at remote WAAS locations	Requirement	Deleted--status indicators to be integrated into overall FAA facilities monitoring capability
Minimum communications satellite coverage for IWAAS/Phase 1 precision landings	2 satellites	1 satellite; dual coverage not necessary for initial system
Full back-up system at each WAAS location	Requirement	Dropped--level of redundancy not cost-effective
Atmospheric data collection for signal error determination	Requirement	Reduced amount of data collected --atmospheric model would provide needed data

GAO Major Revisions to WAAS Requirements

Contract provision	Wilcox contract	Changes in Hughes contract
Electronic data transfer to National Geodetic Survey	Requirement	Data to be transferred by disk
Maximum delay for user receipt of WAAS corrections	Requirement	Deleted as a cost-cutting measure
WAAS signal specifications	N/A	Changed to conform with RTCA recommendations
WAAS safety architecture	N/A	Proposed engineering changes to increase safety/redundancy of WAAS system

GAO FAA's Rationale for Wilcox Termination

- Failed to provide effective program management
 - Did not deliver the contractor team as proposed:
 - staff reorganized
 - understaffed
 - staff unqualified
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GAO FAA's Rationale for Wilcox Termination

- Failed to award key subcontracts as scheduled
 - Potential cost overruns of at least \$100 million
 - Predicted schedule delay of at least 10 months
 - Failed to complete system design review - 6 months overdue
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GAO FAA's Rationale for Wilcox Termination

- Failed to establish program cost and schedule baseline
- Failed to provide adequate cost/schedule reporting

GAO Implications of Ending WAAS at the
Completion of Phase 1

- Programmatic and financial:
 - Within the contract, approximately \$75 million of the remaining \$262.6 million cost of Phases 2 and 3 is needed to support Phase 1 WAAS.
 - WAAS hardware must be upgraded/replaced as planned in Phase 3 (\$25 million).
 - WAAS software development planned for Phase 3 still needed (\$50 million).
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GAO Implications of Ending WAAS at the
Completion of Phase 1

- Outside of the contract:
 - FAA would still have to contract for additional communications satellites (\$32 million/year).
 - FAA would still have to spend \$40 million for planned National Airspace System implementation (e.g., instrument landing procedures) in Phases 2 and 3.
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GAO Implications of Ending WAAS at the
Completion of Phase 1

- Potential linkages and agreements with other countries' wide area augmentations could be jeopardized.
 - Operational and financial:
 - FAA would operate two navigation systems.
 - \$4.2 billion potential O&M to maintain current ground-based navigation aids (over 20 years).
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GAO Implications of Ending WAAS at the
Completion of Phase 1

- \$2 billion to maintain Phase I WAAS (over 20 years).
 - Loss of some user benefits related to avionics cost savings, fuel savings, and direct flight.
 - Limited increases in airspace capacity to meet future air traffic demands.
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GAO Implications of Ending WAAS at the
Completion of Phase 1

- Transition to direct routing dependent on full WAAS capability.
- Full safety enhancements will not be realized, particularly for regional airlines and smaller airports.