United States General Accounting Office

GAO

Testimony

Before the Subcommittee on Aviation, Committee on Transportation and Infrastructure, House of Representatives

For Release on Delivery
expected at
9:30 a.m.
Wednesday
October 1, 1997

NATIONAL AIRSPACE SYSTEM

Observations on the Wide Area Augmentation System

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Mr. Chairman and Members of the Subcommittee:

We are pleased to be here today to discuss the Federal Aviation Administration's (FAA) Wide Area Augmentation System (WAAS) program. FAA is planning a transition from a ground-based civil air navigation system to a satellite-based system using signals generated by the Department of Defense's Global Positioning System (GPS). However, GPS, designed for military purposes, does not satisfy civil air navigation requirements such as the one requiring that the system be available virtually all of the time. FAA is acquiring WAAS—a network of equipment on the ground and in space—to enhance GPS so that the system can meet civil aviation requirements. Satellite-based navigation, using GPS/WAAS, is expected to improve the safety of flight operations, allow the fuel-efficient routing of aircraft, increase airport and airspace capacity to meet future air traffic demands, and enable FAA to phase out its costly network of ground-based navigation aids. By providing positioning information, GPS/WAAS is also expected to benefit the operators of other modes of transportation and other types of users.

The purpose of our testimony today, which is based on ongoing work requested by your Subcommittee, is to aid congressional oversight by providing insights into the cost, schedule, and technical issues that have drawn considerable attention to the WAAS program. Specifically, our testimony will discuss: (1) the likelihood of WAAS' satisfying key performance requirements within current program cost and schedule estimates; (2) the importance of avoiding delays in FAA's timetable for shutting down (decommissioning) ground-based navigation aids; and (3) the potential impact of cost increases and decommissioning delays on the benefit-cost analysis for the WAAS program.

In summary

- While the developers of WAAS and outside experts are confident that WAAS is likely to satisfy most key performance requirements within current program cost and schedule estimates, some concerns are worth noting. Specifically, FAA may use additional augmentations and make procedural changes for aircraft landings if WAAS is not able to deliver the level of service provided by existing ground-based landing systems. Also, FAA may add more space-based equipment to meet performance requirements. FAA expects to make decisions on these matters by late 1998 and late 2000, respectively. If the space-based equipment is added, program costs would grow between $71 million and $192 million above the current total program cost estimate of $2.4 billion. The program's schedule can be expected to slip if arrangements are not made immediately to put this equipment in space.

- To realize the full cost savings from WAAS, FAA will need to avoid delays in decommissioning its ground-based network of navigation aids. FAA estimates that it incurs costs of $166 million annually to maintain this ground-based network. FAA's plans—which envision complete decommissioning of the network by 2010—presume that the full WAAS will become operational (commissioned) in 2001 and that the aviation industry will install the necessary equipment in its aircraft during the remainder of that decade. However, the planned decommissioning could be delayed if the WAAS program's schedule slips or if safety and economic benefits, such as an aircraft's ability to take advantage of more fuel-efficient routes, are not sufficient to cause the industry to switch to satellite-based navigation technology by the end of the next decade.
- Cost increases and decommissioning delays, if they occur, would reduce the net benefits of the WAAS program, but program benefits would still outweigh costs. FAA's July 1997 benefit-cost analysis found that benefits were (1) more than five times greater than costs when passenger time savings were included and all aircraft gained savings from shorter flights, and (2) more than two times greater than costs when passenger time savings were excluded and 30 percent of all aircraft gained savings from shorter flights. Additional analyses done at our request, using pessimistic cost and decommissioning assumptions, found that the WAAS program's benefits are still significantly greater than the costs. However, if the ground-based navigation network is not decommissioned or must remain in place much longer than expected, the net benefits from WAAS would be substantially reduced.

Background

In the 1980s, FAA began considering how a satellite-based navigation system could eventually replace the ground-based system that had long provided navigation guidance to aviation. In August 1995, after years of study and research, FAA contracted with Wilcox Electric to develop WAAS. However, because of concerns about the contractor's performance, FAA terminated the contract in April 1996. In May 1996, the agency entered into an interim contract with Hughes Aircraft. The interim contract with Hughes was subsequently expanded and became final in October 1996.

Under the terms of the WAAS development contract, Hughes will deliver an initial operational capability (Phase 1 WAAS) to FAA by April 1, 1999. The original date written into the Wilcox contract was December 1997. Phase 1

WAAS will be able to support the navigation of aircraft throughout the continental United States for all phases of flight through Category I precision approaches.[1] However, the Phase 1 system will not have sufficient redundancy to continue operations in the event of equipment failures and will have to be backed up by FAA's current ground-based system. FAA expects to conclude the operational testing of Phase 1 WAAS in June 1999 and to commission the system by July 15, 1999. To make WAAS capable of serving as a "sole means" navigation system throughout the United States,[2] FAA plans to expand the system in Phases 2 and 3 of the contract. The Phase 3, or full, WAAS is scheduled to be delivered by October 2001 and commissioned in early 2002.

Our August 1997 report on WAAS to this Subcommittee and others provided details on the history of FAA's cost estimates for WAAS. We found that although FAA knew that the facilities and equipment costs for WAAS could exceed $900 million, the agency presented to the Congress a figure that was some $400 million lower.[3] In September 1997, FAA estimated the total life cycle cost of the WAAS program to be $2.4 billion. Of this amount, about $900 million is for facilities and equipment and $1.5 billion is for operations and maintenance through the year 2016.

Accuracy, integrity, and availability are the major performance requirements for GPS/WAAS. Accuracy is defined as the degree of conformance of an aircraft's position as calculated using GPS/WAAS to its true position. Integrity is the ability to provide timely warnings when the GPS/WAAS is providing erroneous information and thus should not be used for navigation. Availability is the probability that at any given time GPS/WAAS will meet the accuracy and integrity requirements for a specific phase of flight.[4]

[1]FAA currently categorizes landing systems according to their ability to safely guide an aircraft to a runway. A Category I precision landing system provides safe vertical guidance to an aircraft as it descends to a height of not less than 200 feet with runway visibility of at least 1,800 feet.

[2]A "sole means" navigation system must, for a given operation or phase of flight, allow the aircraft to meet all navigation system performance requirements, without having another navigation system on board the aircraft.

[3]See National Airspace System: Questions Concerning FAA's Wide Area Augmentation System (GAO/RCED-97-219R, Aug. 7, 1997). Past GAO reports and testimonies on the augmentation of GPS are listed at the end of this document.

[4]Continuity and service volume are also considered major requirements. However, because they are derived from the accuracy, integrity, and availability requirements, we did not focus on them separately in our analysis. Continuity is the probability that the GPS/WAAS signal will meet accuracy and integrity requirements continuously for a specified period. Service volume is the area of coverage for which the GPS/WAAS signal will meet availability requirements.

WAAS is a system comprising a network of ground stations and geostationary (GEO) communications satellites.

- Reference stations (up to 54 sites) on the ground will serve as the primary data collection sites for WAAS. These stations receive data from GPS and GEO satellites.
- Master stations (up to 8 sites) on the ground will process data from the reference stations to determine and verify corrections for each GPS satellite. These stations also validate the transmitted corrections.
- Ground earth stations (up to 8 sites) will, among other things, receive WAAS message data from the master stations, and transmit and validate the message to the GEO satellites.
- GEO satellites will transmit wide-area accuracy corrections and integrity messages to aircraft and also serve as additional sources of signals similar to GPS signals.
- The ground communications system will transmit information among the reference stations, master stations, and ground stations.

For pilots to use GPS/WAAS for navigation, their aircraft must be equipped with receivers that process the information carried by the GPS and GEO signals. The receivers will enable the pilots to determine the time and their aircrafts' three-dimensional position (latitude, longitude, and altitude).

Concerns Exist About Whether WAAS Can Satisfy Performance Requirements Within Budget and on Schedule

While system developers and outside experts have confidence that WAAS can achieve most key performance requirements within current cost and schedule estimates, four concerns are worth noting:[5] (1) the ability of WAAS to provide the level of service for precision approaches provided by existing ground-based systems; (2) the ability of computers to process the large quantities of GPS/WAAS data within a few seconds; (3) the vulnerability of GPS/WAAS signals to interference; and (4) the need for additional satellites to achieve the availability requirement.

Regarding the first concern, it is uncertain whether WAAS can meet the requirement that the GPS/WAAS signal be available for precision approaches all but about 11 hours per year. Under current definitions based on ground-based navigation technology, a Category I system provides a level of service that allows aircraft to descend to an altitude (height) of not less than 200 feet when visibility is at least 1,800 feet. If WAAS cannot meet this requirement, FAA may incur additional costs to install local area

[5] See app. I for additional information on achievability of requirements.

augmentation systems at more airports than expected.[6] The agency may also change the procedures by which pilots can make precision approaches. One procedural option under consideration is that FAA would require pilots to visually recognize additional approach markings before completing a landing. A decision is expected on any needed procedural changes by late 1998.

A second concern is the integrity requirement that calls for the system to sound an alarm within 5.2 seconds when it receives hazardously misleading information, such as a correction that is wrong and would result in an aircraft operator being placed in a dangerous situation. The large volume of data that must be processed within a few seconds to meet this requirement is beyond the capabilities of computer data processors that are commercially available. However, FAA is testing newly developed processors and is confident that they will meet the agency's needs.

A third concern exists about the possibility that the GPS/WAAS signal could prove vulnerable to unintentional or intentional radiofrequency interference that could affect the signal's availability or accuracy and, ultimately, flight safety. These vulnerabilities are common to ground- and satellite-based navigation aids. Because GPS broadcasts its signal at a very low power level, its signal is somewhat more vulnerable to interference. FAA expects to complete a vulnerability assessment for WAAS in October 1997. Once the assessment is completed, countermeasures, if needed, would be identified. Because of the sensitivity of this issue, we cannot go into details in this public hearing. FAA has stated that it will offer a private briefing for the Subcommittee.

A fourth concern is whether FAA may have to add more GEO satellites to meet the availability requirement. FAA requires that GPS/WAAS be available virtually 100 percent of the time—all but about 5 minutes a year—for the phases of flight leading up to precision approaches. Although FAA originally thought it could meet this requirement by using four geostationary communications satellites, the agency may need five or six. If so, FAA could continue using one or two of the GEO satellites currently in space or obtain others. FAA intends to decide on the need for additional satellites by late 2000. Even with the added satellites, there may be isolated areas of air space, such as the far northern and western areas of Alaska, where the requirements may not be met. In such areas, according to FAA officials, FAA intends to use ground-based systems or local area

[6] Local area augmentation systems enhance GPS to provide precision approaches under the most stringent conditions.

augmentation systems to provide a level of service that is at least equal to what is provided today.

The addition of one or two GEO satellites would increase the program cost beyond the current estimate of $2.4 billion. FAA expects that adding one or two GEO satellites would cost between $71 million and $192 million over the WAAS life cycle (2001-2016).[7]

FAA faces a very tight time frame for putting the GEO satellites in space. FAA intends to work with the Defense Department to begin the acquisition process this month, but it typically takes 4 years to acquire, launch, and check out a GEO satellite. Given FAA's October 2001 milestone for the delivery of the full WAAS, any delays in putting the GEO satellites in space could cause the WAAS program's schedule to slip.

Full Cost Savings From WAAS Tied to FAA's Decommissioning of Ground-Based System

To get the full cost savings from WAAS, FAA will need to decommission its ground-based network of navigation aids, which now costs the agency $166 million annually to maintain. FAA's plan presumes that both its current ground-based system and the new satellite-based system will be in place from the time that the full, Phase 3 WAAS is commissioned until the decommissioning of the ground-based network is completed in 2010.[8] FAA's plan recognizes that a critical factor in the transition will be the widespread installation by commercial and general aviation operators of GPS/WAAS avionics aboard their aircraft.

FAA believes that the safety and economic benefits of GPS/WAAS will motivate aircraft operators to install GPS/WAAS avionics in the 5- to 6-year period after the services become available in 2001. The safety improvements include the vertical guidance WAAS will give aircraft during approach and landing at airports where no precision approach capability currently exists. This guidance enables aircraft to follow a smooth glide path safely to the runway. Other benefits include the cost savings that aircraft operators could realize by using one type of navigation equipment in the cockpit for all phases of flight and by flying more direct, fuel-efficient routes. FAA also expects that when it begins decommissioning ground-based navigation aids, aircraft that are not equipped with GPS/WAAS avionics will have to fly less direct routes and will have limits on the precision approach options available to them. As a result, there will be added incentives for aircraft operators to switch to satellite technology.

[7]Program costs are presented in then-year dollars.

[8]FAA's Plan for Transition to GPS-Based Navigation and Landing Guidance (July 1996).

Nevertheless, FAA's plans could be impeded if the WAAS program's schedule slips or if safety and economic benefits are not sufficient to cause the aviation industry to switch quickly to satellite technology. As already discussed, the primary concern about whether the WAAS requirements can be achieved on time is the potential for delays in putting the communications satellites in space.

Economic considerations, however, could cause commercial and general aviation aircraft operators to switch to GPS/WAAS avionics more slowly than FAA envisioned in its Transition Plan. According to the U.S. GPS Industry Council, the typical GPS receiver used by large commercial aircraft costs between $20,000 and $50,000, and the typical GPS receiver used by smaller general aviation aircraft capable of flying when visibility is limited costs between $5,000 and $15,000. Database changes needed to keep the receivers up to date now cost $70 to $100 a month. Expenses for installing the equipment and training the pilots to use it would be additional.

Airlines already recognize the value of GPS/WAAS for determining the position of aircraft flying over the oceans, where no ground-based navigation aids exist, and have been installing GPS receivers for that purpose. For flights over the continental United States, the airlines' interest is not so clear cut. Responding to our questions, the organization representing the airlines, the Air Transport Association, wrote that

"Airspace users must have a compelling reason to change from their current ground-based avionics to space-based avionics. Simply stating that the technology is better is not enough. There must be real operational benefits for changing or the equipment will have to [be] mandated. Otherwise, avionics change will be extremely slow."

The organization representing general aviation, the Aircraft Owners and Pilots Association, has argued that the present cost of GPS/WAAS avionics, including the cost of maintaining a current database, is not affordable for all segments of the general aviation community. Representatives of the Association told us that FAA's plan for decommissioning by 2010 would be realistic if (1) FAA provides routes that are more direct, (2) more inexpensive avionics are available, (3) FAA places a high priority on certifying approach procedures where none currently exist, (4) inexpensive database updates for GPS receivers can be obtained electronically from FAA, and (5) FAA does not require aircraft operators to incur the added expense of carrying redundant (dual) GPS/WAAS receivers.

FAA is currently working with industry to resolve these concerns. Even if the Association's concerns are satisfied, however, FAA could still face a slower-than-expected conversion to GPS/WAAS avionics if individual aircraft operators do not conclude that the benefits of installing the new navigation equipment outweigh their costs. FAA would then have to make a difficult choice—either slow down its decommissioning of ground-based navigation aids or, in effect, require conversion by proceeding with decommissioning as planned.

Cost Increases and Delays in Decommissioning Reduce Net Benefits of WAAS, but Benefits Still Exceed Costs

In making investment decisions, FAA conducts benefit-cost analyses to determine if the benefits to be derived from acquiring new equipment outweigh the costs. In the case of WAAS, the benefits to the government include the cost savings from reduced maintenance of the existing, ground-based network of navigation aids and the avoidance of capital expenditures for replacing those aids. The benefits to aircraft operators—the users of the system—include the reduction in accident-related costs (from death, injury, and property damage) because WAAS landing signals would be available at airports that currently lack precision landing capability. Operators could also realize "direct route" savings that result from the shorter flight times on restructured, more direct routes that aircraft can fly using GPS/WAAS. The costs include the life cycle costs for WAAS facilities and equipment as well as operations and maintenance.

Despite differing assumptions used in calculating benefit-cost ratios, FAA's analyses dating back to 1994 have always found WAAS to be a cost-beneficial investment—that is, the benefits clearly exceeded the costs, resulting in benefit-cost ratios in excess of 1.[9] The most recent 1997 analysis found (1) a 5.2 ratio of benefits to costs when passenger time savings were included in the direct route benefits and all aircraft would gain a savings of 1 minute per flight from shorter routes, and (2) a 2.2 ratio when passenger time savings were excluded and 30 percent of all aircraft would gain a savings of 1 minute per flight.[10] When these two cases were evaluated in dollar terms, the net benefits of WAAS were $5.3 billion and

[9]Although WAAS will benefit nonaviation users, these benefits were not included in FAA's analysis. If these additional benefits were included, the benefit-cost ratio would increase.

[10]Cost-Benefit Analysis of the Wide Area Augmentation System (draft), July 1997.

$1.5 billion, respectively.[11] (See app. II for details on FAA's benefit-cost analyses for the WAAS program in 1994, 1996, and 1997.)

To understand the impact of the potential cost increases and decommissioning delays previously discussed, we requested that FAA's support contractor perform alternative runs of the benefit-cost analysis.[12] FAA's 1997 analysis served as the base case for comparison purposes. One pessimistic scenario that we requested made the following alternative assumptions from the base case: (1) the development cost of the primary WAAS contract would increase by 15 percent, (2) the leasing costs for communications satellites would increase by 50 percent, and (3) the decommissioning of the ground-based navigation aids would be delayed by 5 years.

Using these assumptions, the contractor's analysis found that the benefit-cost ratio would be 4.6 when passenger time savings were included and all aircraft gained savings from shorter flights and 1.7 when passenger time savings were excluded and 30 percent of all aircraft gained savings from shorter flights. In dollar terms, net benefits declined substantially—about $490 million—when going from the base case to the pessimistic scenario. When scenarios were run using the three assumptions in turn, the analysis showed that the decommissioning delay of 5 years caused about $370 million of the decline in net benefits. The cost increases for contract development and satellite leasing contributed the remainder. We also asked for a run with a more pessimistic scenario in which the contract development and satellite leasing costs would increase by the same amount but ground-based navigation aids would never be decommissioned. In this case, the decline in net benefits totaled about $700 million.

Ultimately, even when pessimistic assumptions were used, the analysis found that the benefits of the WAAS program still clearly outweighed its costs. However, delays in decommissioning or the retention of ground-based navigation aids would cause substantial decreases in the net benefits of the WAAS program.

[11]As an alternative to the benefit-cost ratio, where the present value of benefits are divided by the present value of costs, analysts sometimes calculate the present value of net benefits. This value is equal to the present value of benefits minus the present value of costs. When using alternative assumptions for calculating benefits and costs, the present value of net benefits can be a useful tool for making comparisons.

[12]While we did not perform an extensive review of the contractor's model used to calculate benefit-cost ratios, the model appeared to be reasonably constructed. For example, future benefits and costs were discounted appropriately.

Agency Comments

We received comments on a draft of this testimony from officials of the Department of Transportation and FAA, including FAA's Deputy Program Manager of the GPS Integrated Product Team and the WAAS Program Manager. These officials expressed general agreement with the findings of the testimony, considered it well-balanced, and provided clarifying and technical suggestions, which we incorporated as appropriate.

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

Achievability of WAAS Performance Requirements

Phase 3 WAAS requirements	Remarks
Availability: Probability that the system will provide an accurate and continuous navigation signal for each phase of flight	
En route through nonprecision approach: 99.999% availability (i.e., unavailable less than 5 minutes a year)	FAA may need to add one or two GEO satellites to the four it planned to procure. Also, FAA is investigating the optimal placement of GEO satellites in orbit. But in isolated areas such as the far northern and western areas of Alaska the requirement may not be met.
Precision approach: 99.9% available (i.e., unavailable 11 hours a year)	FAA may field up to 54 ground stations, and Canada and Mexico may field up to 21. Between late 1998 and mid-1999, FAA will determine how many ground stations are needed based on system test results. FAA may be required to make changes to approach procedures to meet this requirement.
Accuracy: Percentage of time that an aircraft's GPS position is within a given distance of the aircraft's true position	
En route through nonprecision approach: Within 100 meters 95% of the time—During periods when this standard cannot be met (up to a cumulative 72 minutes a day), system safety will be guaranteed by a proposed 2-mile horizontal protection limit. Within 500 meters 99.999% of the time—During periods when this standard cannot be met (up to a cumulative 6 seconds a day), system safety will be guaranteed by a proposed 2-mile horizontal protection limit.	No major concerns have been raised by system developers or outside parties about these requirements because the existing GPS already guarantees this level of performance. Feasibility testing at FAA's National Satellite Test Bed (NSTB) has validated that these requirements have been met. FAA will revalidate whether the WAAS software and hardware will achieve these requirements.
Precision approach: Within 7.6 meters 95% of the time—During periods when this standard cannot be met (up to a cumulative 72 minutes a day), system safety will be guaranteed by a proposed 63-foot horizontal and vertical protection limit.	No major concerns have been raised by system developers or outside parties about this requirement. FAA's NSTB has achieved this level of accuracy. During WAAS software and hardware testing, FAA will validate that this requirement can be met.

(continued)

Phase 3 WAAS requirements	Remarks
Integrity: Ability of the system to provide users with timely warnings about erroneous information	
Probability that the system will not detect hazardously misleading information	
En route through nonprecision approach: 1 chance in 10 million during 1 hour of system operation **Precision approach:** 1 chance in 400 million per approach (an approach is the final 2-1/2 minutes of flight)	No major concerns have been raised by system developers and outside parties about these requirements. FAA plans to acquire safety-certified equipment and software, and during hardware and software testing also plans to collect and analyze data to provide increased assurance that the requirements will be met.
Maximum number of seconds elapsed before an alarm sounds	
En route through nonprecision approach: 8 seconds **Precision approach:** 5.2 seconds	The feasibility of meeting the 5.2-second requirement (and, therefore, the 8-second requirement) has been demonstrated at FAA's NSTB. But as WAAS processes more data, its ability to meet the requirement may decline. FAA's present analysis shows that the requirement is being marginally satisfied. FAA is looking at faster processing equipment to accommodate the expected increase in data.
Continuity: Probability that service will continue to be available for a specified period	
En route through nonprecision approach: 1 chance in 100 million per hour of flight operations that the **accuracy** requirement will not be met	FAA may need to add one or two GEO satellites to the four it planned to procure or it may have to relax the requirement. Experts believe relaxing the requirement may be possible, but FAA has to determine the impact on safety if, in the event of a catastrophic loss of both GPS and WAAS, air traffic controllers might have to rely on radar to separate and direct aircraft.
En route through nonprecision approach: 1 chance in 100,000 per hour of flight operations that the **integrity** requirement will not be met	No major concerns have been raised by system developers or outside parties because existing aircraft systems have demonstrated this ability. During testing, FAA will review contractor data to validate that the integrity requirement can be met.
Precision approach: Per approach, 1 chance in 550,000 that the **accuracy and integrity** requirements will not be met (an approach is the final 2-1/2 minutes of flight)	No major concerns have been raised by system developers or outside parties about this requirement on the basis of the preliminary analysis. But because of the volume of data needed to validate compliance with this requirement, FAA is gathering additional data and exploring alternative methods for validating that the requirement can be met.

(continued)

Phase 3 WAAS requirements	Remarks
Service volume: The air space in which all other performance requirements must be met	
En route through nonprecision approach: The continental United States, Alaska, Hawaii, the Caribbean, the Gulf of Mexico, and major portions of the Atlantic and the Pacific	FAA may need to add one or two GEO satellites to the four it planned to procure. Also, FAA is investigating the optimal placement of GEO satellites in orbit. But in isolated areas such as eastern Canada and oceanic airspace the requirement may not be met.
Precision approach: The continental United States, Alaska, Hawaii, and Puerto Rico	FAA may field up to 54 ground stations, and Canada and Mexico may field up to 21. Between late 1998 and mid-1999, FAA will determine how many ground stations are needed based on system test results. FAA may be required to make changes to approach procedures to meet this requirement.

Results of FAA's Benefit-Cost Analyses, 1994, 1996, and 1997

The results of FAA's benefit-cost analyses of the WAAS program in 1994, 1996, and 1997 are summarized in table II-1. On the benefit side, benefits to the government accrue from the reduced maintenance of the existing, ground-based network of navigation aids and the avoidance of capital expenditures for replacing these aids. Benefits to users—the aircraft operators—fall into five categories:

- Efficiency benefits derive from having precision landing capability at airports where it does not now exist.
- Avionics cost savings reflect how GPS/WAAS will enable users to reduce the proliferation of avionics equipment in their cockpits.
- Fuel savings reflect the use of less fuel to fly aircraft that carry less avionics equipment.
- Safety benefits stem from the reduction in accident-related costs (death, injury, and property damage) because of the availability of WAAS landing signals at airports that presently lack a precision landing capability.
- Direct route savings result from the shorter flight times associated with restructured, more direct routes that aircraft can fly.

Table II-1: FAA's Analysis of Benefits and Costs for WAAS Project, 1994, 1996, and 1997

Dollars in millions

	1994	1996	1997 High	1997 Low
Benefits				
Government	1,385	943	754	754
User				
Efficiency	1,051	768	286	148
Avionics	1,312	1,109	546	546
Fuel	98	95	13	13
Safety	560	1,384	624	624
Direct Route		5,489	4,299	637
Total	**4,406**	**9,789**	**6,521**	**2,722**
Costs				
R&D, F&E			540	540
O&M			720	720
Total	**1,081**	**1,051**	**1,260**	**1,260**
Benefit-Cost Ratio	**4.1**	**9.3**	**5.2**	**2.2**

Source: Federal Aviation Administration.

FAA's 1997 benefit-cost analysis took a more conservative approach than previous versions of the model in estimating the benefit-cost ratio. That is, compared with the previous analyses, the assumptions underlying the current study increased the expected costs of WAAS and simultaneously reduced the expected benefits, which resulted in a lower benefit-cost ratio than found in the previous versions of the study. The higher total costs in the 1997 version were largely due to the inclusion of the costs of decommissioning land-based navigation systems that were not included in any earlier versions of the study. On the benefit side, several changes in key assumptions led to reduced expected benefits including (1) a shorter life cycle for the project, (2) a reduction in the assumed "saved" costs from phasing out ground-based navigation systems,[13] (3) a reduction in estimated safety benefits based on the use of the more recent accident data,[14] and (4) a reduction in the expected flight time savings resulting from more direct routes.

[13]Specifically, the analyst assumed that old equipment would have been replaced at a slower rate so that savings from not having to replace that equipment were reduced.

[14]In previous versions of the study, older data on accident rates were used. Since rates of accidents have been declining with time, use of the most recent data reduced the expected safety benefits from WAAS.

Related GAO Products

National Airspace System: Questions Concerning FAA's Wide Area Augmentation System (GAO/RCED-97-219R, Aug. 7, 1997).

Air Traffic Control: Improved Cost Information Needed to Make Billion Dollar Modernization Investment Decisions (GAO/AIMD-97-20, Jan. 22, 1997).

Global Positioning System Augmentations (GAO/RCED-96-74R, Feb. 6, 1996).

National Airspace System: Assessment of FAA's Efforts to Augment the Global Positioning System (GAO/T-RCED-95-219, June 8, 1995).

Air Traffic Control: Status of FAA's Modernization Program (GAO/RCED-95-175FS, May 26, 1995).

Aviation Research: Perspectives on FAA's Efforts to Develop New Technology (GAO/T-RCED-95-193, May 16, 1995).

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

Global Positioning Technology: Opportunities for Greater Federal Agency Joint Development and Use (GAO/RCED-94-280, Sept. 28, 1994).

Airspace System: Emerging Technologies May Offer Alternatives to the Instrument Landing System (GAO/RCED-93-33, Nov. 13, 1992).

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