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Observations on FAA's Satellite Navigation Efforts

Statement of
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Mr. Chairman and Members of the Subcommittee:

We appreciate the opportunity to discuss the Federal Aviation Administration's (FAA) Wide Area Augmentation System (WAAS). We have provided oversight and reported on the WAAS program for several years.[1]

As part of its overall plan for modernizing the National Airspace System, FAA plans to transition from a ground-based to satellite-based system using signals generated by the Department of Defense's Global Positioning System (GPS). Because GPS alone cannot meet all FAA's requirements for civil aviation, FAA is developing new systems, including WAAS, to augment GPS to provide navigation services through all phases of flight, including precision approaches. Airspace users must equip with new avionics to take advantage of new satellite-based systems. Expected benefits from satellite navigation include improved safety and enhanced capacity.

Today, I would like to make two points.

- First, there has been a great deal of uncertainty over the years regarding how much WAAS will cost, when it will be delivered, and what benefits can be obtained. WAAS is now expected to cost $2.9 billion in program costs, and Congress has appropriated over $500 million for the effort. Since 1997, program costs have increased by over $700 million (excluding costs for additional communication satellites), and the new navigation system has been delayed by at least several years.

  In 1995, FAA believed that WAAS could provide a *sole means* of navigation, meaning that GPS/WAAS—with appropriate augmentations—could satisfy the required performance as the only navigation system installed in an aircraft or the only service provided by FAA.[2] Besides benefits for air carriers and general aviation, a sole means system offered FAA benefits because it would have allowed the agency to save millions annually by decommissioning existing ground-based navigation aids. Because of concerns about interference with the GPS signal, FAA, in 1999, recognized the need for a secondary system and is currently determining its composition.

[1] See Observations on the Federal Aviation Administration's Plan to Use Satellite Technology for Air Traffic Management (OIG Report AV-1998-001, October 1997); Wide Area Augmentation System (OIG Report AV-1998-117, May 1998); Air Traffic Control Modernization (OIG Report AV-1999-065, March 1999); and Key Safety, Modernization, and Financial Issues Facing FAA (OIG Report AV-2000-072, March 2000).

[2] FAA is also developing the Local Area Augmentation System (LAAS) as part of the transition to satellite-based navigation. LAAS is intended to complement WAAS by providing more demanding precision approach and landing capability for high-density airports, and provide precision approach services where WAAS could not.

Recently, WAAS experienced complex hardware and software problems, and concerns exist about the system's *integrity*. Integrity refers to the ability of the system to alert the pilot when the WAAS signal cannot be relied on and should not be used. This is absolutely critical for the final phases of flight when pilots prepare to land an aircraft.

FAA's analysis shows that WAAS safety processors failed to prevent hazardously misleading information from being broadcast on several occasions since last December. As a result, WAAS will not provide Category I precision approach capability[3] in September 2000, as promised. It is uncertain when and if such services can be delivered, but FAA believes it can provide some level of precision approach capability (but less than Category I) some time in 2002.

Despite problems, industry stakeholders believe WAAS can provide benefits. For example, they see benefits in terms of more flexible routes (for airspace users who have not already equipped with other systems) and some level of precision landing capability for airports that do not currently have it. Also, a more accurate signal for other satellite-based technologies could prove useful in enhancing runway safety. However, these benefits can only be realized if WAAS technical and integrity concerns can be resolved.

FAA has formed a panel of experts, known as the WAAS Integrity and Performance Panel (or WIPP) to determine how long it will take and how much it will cost to resolve WAAS technical problems. This panel will provide FAA with a final report in December 2000. In response to our recommendation, FAA has also established an independent review board under the auspices of the Institute for Defense Analyses to review the WIPP's work and FAA's organizational structure for managing WAAS. The board's final report is planned for January 2001. A clear picture of WAAS performance, cost, and schedule will not be available until these two groups have completed their work.

A related issue focuses on how FAA will certify WAAS as safe for pilots to use. There are two schools of thought regarding how WAAS can be certified—one school believes that sound analyses and simulations will be sufficient to prove integrity; the other believes that a combination of operational experience and sound analyses will be needed to prove the system is safe. The WIPP is expected to provide insight into how WAAS can be

[3] Category I precision approaches provide for an approach to a height above touchdown of not less than 200 feet and visibility of ½mile.

certified for specific levels of performance. Resolution of this issue has important cost and schedule implications.

- Second, notwithstanding cost increases, delays, and uncertainty regarding benefits, we believe it is premature to make judgments about the future of WAAS for a number of reasons. Satellite-based navigation involves cutting-edge technology and plays an important part in FAA's plans for modernizing the National Airspace System.

  The potential benefits of WAAS (if they can be achieved) appear to be significant, and the Congress, FAA, and aviation stakeholders need to know if benefits can be obtained, at what cost, and in what timeframes. Also, FAA's efforts have international implications because other nations are planning satellite navigation systems of their own for civil aviation.

  FAA officials indicated that new cost and schedule baselines for WAAS could be developed by late September. However, FAA should rethink these plans and wait until technical and independent reviews are complete in the December/January timeframe.

  Until technical reviews are complete, FAA should proceed cautiously with this acquisition. There are two "watch items" that focus on contract management and oversight and the technical expertise needed to solve problems.

  In March, we recommended that FAA make a significant downward adjustment in the *contract burn rate* (about $4 million a month) until technical solutions are clearly identified. FAA agreed but noted that reductions may be offset by additional efforts to resolve WAAS integrity problems and implement solutions. We tried to determine the contract burn rate for April and May but could not because we received conflicting information from Raytheon, and the data we reviewed from FAA may not reflect all costs incurred for the time period because of a lag time in billing.

  While parallel activities continue to correct problems and pursue WAAS development, FAA must be judicious about how it spends funds on a system that has an uncertain end-state. Given that WAAS is a cost-plus contract, we are recommending that the contract undergo a cost incurred audit and a series of unannounced labor/floor checks by the Defense Contract Audit Agency. We will work with FAA to structure these audits accordingly.

Cost, Schedule, and Anticipated Benefits of WAAS

The WAAS Program has experienced a long history of uncertainty regarding how much WAAS will cost, when it will be delivered, and what benefits can be obtained. In May 1994, FAA estimated the total cost for WAAS to be $509 million but this did not include major cost items, such as communications satellites. FAA's July 1997 cost estimates of $892 million (program costs) were more reflective of the agency's needs. The most recent WAAS cost estimate of $2.9 billion (program costs) reflects increases associated with adding 4 additional years to the effort, and shifts the costs of satellite communications to the Facilities and Equipment account from the Operations and Maintenance account.

Since 1997 alone, WAAS Program costs have increased by over $700 million[4] (excluding costs for additional communication satellites), and the new navigation system has been delayed by several years. The charts below show costs and schedules for WAAS as of 1999.

Costs of the WAAS Program
(Dollars in Millions)

COST ELEMENTS	Acquisition Program Baseline May 1994	Joint Resources Council July 1997	Sat/Nav Investment Analysis Report January 1998	Sat/Nav Investment Analysis Report September 1999
Facilities & Equipment	**396.4**	**892.4**	**1,006.6**	**2,978.0**
Operations & Maintenance	**112.6**	**1,519.0**	**2,042.6**	**704.0**
Total	**$509.0**	**$2,411.4**	**$3,049.2**	**3,682.0**

Source: OIG analysis of FAA investment analyses data.

[4] To determine WAAS cost increases, we subtracted the 1997 WAAS program costs of $892 million from the latest program costs of $2.9 billion to arrive at a total of $2.08 billion. We then subtracted satellite communications costs of $1.3 billion from the derived total to obtain an increase of over $700 million in WAAS program costs.

Schedule for the WAAS Program

WAAS	National Airspace System Architecture 2.0 (October 1996)	Draft National Airspace System Architecture 3.0 (September 1997)	National Airspace System Architecture 4.0 (January 1999)
Initial Operating Capability	**1998**	**1999**	**2000**
Full Operating Capability	**2001**	**2002**	**2003-2007**

- Initial Operating Capability: This refers to the initial stage of WAAS, which was expected to be capable of supporting navigation and Category I precision approaches. The system would lack the required internal redundancy and availability. According to FAA, the WAAS signal would only be available over segments of the continental United States and other areas. FAA would need to acquire additional communications satellites to expand coverage of the WAAS signal.

- Full Operating Capability: This refers to the final stage of WAAS, which was expected to be capable of supporting navigation and Category I precision approaches with the required internal redundancy and availability. The WAAS signal will be available over the entire continental United States, Hawaii, Puerto Rico, and most of Alaska.

Satellite Navigation Performance and Benefits

In 1995, FAA believed that WAAS could provide a *sole means* of navigation, meaning that GPS/WAAS—with appropriate augmentations—could satisfy the required performance as the only navigation system installed in an aircraft or the only service provided by FAA. This was a major benefit because it would have allowed FAA to save millions annually by decommissioning all existing ground-based navigation aids.

Because of concerns about interference with the GPS signal, FAA has recognized the need for a secondary system of some type and is working on the details of its composition. We cautioned FAA about the need for a secondary system some time ago in previous reports and testimonies.

Realizing the benefits of satellite-based navigation also depends on the Local Area Augmentation System (LAAS). LAAS is expected to provide Category I as well as more demanding services (Category II and III).[5] LAAS is intended to complement WAAS by providing more demanding precision approach and landing capability for high-density airports, and provide Category I service where WAAS coverage was not sufficient. For the most part, FAA expected that smaller airports (without ground-based landing systems) would rely on WAAS for precision approach capability.

LAAS is now playing a much more prominent role in FAA's plans. LAAS can be implemented independently from WAAS, and requires the development and testing of a new generation of ground systems for augmenting GPS. LAAS enjoys industry support and is being developed through two joint Government/industry partnerships: one led by Raytheon, the other by Honeywell. FAA and industry plan to have LAAS systems operational by the end of 2002. FAA estimates the program costs to develop and implement LAAS at 160 airports to be $720 million.

The Key Cost, Schedule, and Benefits Driver Focuses on Integrity of the WAAS System

In the past year, WAAS has experienced complex hardware and software problems, including the loss of the WAAS signal in space for about 100 minutes. Problems with the system's integrity were also identified. The cost and schedule implications of fixing these problems have yet to be determined. Past and present problems with WAAS are traceable to overambitious schedules, complex software development, and combining development and production activities.

[5] LAAS is being developed to provide Category II and III precision approach capability, which requires a very high level of performance. Category II is a precision approach with a decision height of less than 200 feet. Category III is a precision approach with a decision height of less than 100 feet.

The key cost and schedule driver for the WAAS program now focuses on the *integrity* of the system. Integrity refers to the ability of the WAAS system to alert the pilot when the WAAS signal cannot be relied on and should not be used. This is absolutely critical for the final phases of flight when pilots prepare to land an aircraft. Thus, resolving the integrity concerns is critical for WAAS to provide precision approach capability.

FAA analysis indicates that WAAS safety processors—systems that monitor and verify the WAAS signal—do not work properly. In December 1999, safety processors failed to detect an instance where *"hazardously misleading information"* was transmitted. Since that time, two more instances that were not detected have occurred.

As a result of these problems, WAAS will not provide Category I precision approach capability in September 2000 as promised, and it is uncertain when FAA will be able to provide the service. Resolving these problems is critical because the bulk of benefits from WAAS are expected to accrue from providing precision approach capability to airports that currently do not have such service.[6] FAA believes that it can deliver WAAS with some precision approach capability—*but less than Category I*— some time in 2002.[7]

It is important to recognize that considerable *development* work will be required to develop the necessary algorithms and software to resolve integrity concerns, and some WAAS components may need to be redesigned. *A major redesign effort of WAAS components, principally the safety processor, could increase program costs and result in additional delays beyond 2002.*

[6] Adding Category I precision approach capability to these airports would also require investments in runway lights and other improvements.

[7] This level of performance is referred to as lateral navigation and vertical navigation, or "LNAV/VNAV" for short.

FAA and Raytheon are working with a panel of experts (known as the WAAS Integrity and Performance Panel, or "WIPP") to determine how long it will take and how much it will cost to resolve the technical problems, and for WAAS to meet expectations for "Category I look-alike" service. The panel is expected to report to FAA in July regarding a path to achieve a level of precision approach capability (but less than Category I), and report in December regarding a path to achieve Category I performance.

Despite problems and diminished performance, industry stakeholders continue to express support for WAAS. Assuming that technical problems are addressed, the system is certified as safe, and users equip with new avionics, FAA and industry believe that WAAS could provide the following benefits:

- More flexible routes for commercial and general aviation pilots than the current ground-based system offers today. This would not be the case for airspace users who have already equipped with Flight Management Systems or other sophisticated onboard avionics and can fly more flexible routes in the en route environment.

- Some precision approach capability (approach minimums of 350 feet/1-mile) at airports. This would be valuable at airports that currently do not have ground-based navigation systems, such as an Instrument Landing System.

- A more accurate signal for other satellite-based technologies, such as Automatic Dependent Surveillance-Broadcast (ADS-B), for improving a pilot's situational awareness and preventing runway incursions as well as enhancing moving map displays of cockpit information.

Important Issues With WAAS Need to Be Addressed

Notwithstanding cost increases, delays, and uncertainty regarding benefits, it is premature to make judgments about the future of WAAS for several reasons. Satellite-based navigation involves cutting-edge technology and plays an important part in FAA's plans for modernizing the National Airspace System. Further, the potential benefits of WAAS (if they can be achieved) appear to be significant.

Also, FAA has made substantial investments in satellite-based navigation initiatives (over $500 million has been appropriated for WAAS alone) and these efforts have important international dimensions. Other nations as well as the European Union are planning and building satellite-based navigation systems for civil aviation.

In view of the highly technical nature of WAAS integrity and performance problems, we recommended that FAA obtain views from an independent, scientific group that had no vested financial interests in the outcome. FAA agreed and formed an independent review board for WAAS under the auspices of the Institute for Defense Analyses, which will report directly to the Administrator. This board will review the WIPP's work, FAA's organizational structure, and various alternatives. The board is currently selecting members and a final report is planned for January 2001, which is why the Congress, FAA, and stakeholders will not have a clear picture of WAAS costs, schedule, and benefits until next year. FAA should formally transmit the report of the independent review board to the appropriate Congressional Committees.

A key unresolved issue focuses on how FAA will certify WAAS—as well as other satellite-based systems, such as LAAS—as safe for pilots to use. The goal of the

certification process is to ensure that safeguards are in place to preclude pilots from acting on misleading information. To certify WAAS, all air and ground components must undergo a safety analysis to determine how potential problems (including worst case scenarios) will be mitigated and their potential for affecting the safety of flight.

FAA has little experience in conducting safety assessments of new communications, navigation, and surveillance technologies. WAAS represents one of the first times FAA will certify a complex satellite-based navigation system (all air and ground components) for such demanding services. There are two schools of thought regarding how WAAS can be certified—one school believes that sound analyses and simulations will be sufficient to prove integrity, the other believes that a combination of operational experience and sound analyses will be needed to prove the system is safe. The WIPP—the expert panel addressing WAAS integrity issues—is expected to provide insight into how WAAS can be certified for specific levels of performance. Resolution of this issue has important cost and schedule implications.

There are simply too many uncertainties about WAAS to make firm judgments about its future. More informative cost, schedule, and performance baselines are at least 6 months away because technical and independent reviews of WAAS will not be complete until the December/January timeframe. FAA officials believe that new cost and schedule baselines could be available in late September. We believe FAA should rethink its plans. Until technical and independent reviews are complete, there are several "watch items" that need to be addressed.

The first watch item is contract management and oversight. The WAAS contract is a cost-plus agreement, meaning that FAA pays for all costs incurred. To date, FAA has spent approximately $260 million on the $535 million WAAS contract.

Earlier this year, in March, we recommended that the agency make a significant downward adjustment in the *contract burn rate* (about $4 million a month) until solutions are clearly identified.[8] FAA agreed but noted that reductions may be offset by additional efforts to resolve WAAS integrity problems and implement solutions. We tried to determine the contract burn rate for April and May but could not because we received conflicting information from Raytheon, and the data we reviewed from FAA may not reflect all costs incurred for the time period because of a lag time in billing.

While parallel development and production activities continue for WAAS, FAA must be judicious about how it spends funds on a system that has an uncertain end-state. Given that WAAS is a cost-plus contract, we are recommending that the contract undergo a cost incurred audit and a series of unannounced floor/labor checks by the Defense Contract Audit Agency. We will work with FAA to structure these audits accordingly.

In addition, an important tool in monitoring a cost-plus contract is *earned value management (EVM)*. EVM provides insight into overall progress of software-intensive acquisitions and can help FAA spot problems before they result in major cost increases and schedule slips. Our review of contract files shows that Raytheon has been reporting inaccurate cost and schedule data, thereby limiting EVM as a management tool. Raytheon's most recent EVM report we reviewed—April 2000—does not reflect all work being done. FAA needs to obtain reliable EVM information to monitor WAAS. As we have noted in a previous report,[9] the agency can and should withhold payments if EVM reporting does not improve.

[8] See Key Safety, Modernization, and Financial Issues Facing FAA (OIG Report AV-2000-072, March 22, 2000).
[9] See Management of Software-Intensive Acquisitions for Free Flight Phase 1 (OIG report AV-2000-028, December 21, 1999).

Once solutions are identified, FAA must make every effort to ensure that the contractor properly uses EVM.

Another watch item is the level of FAA and contractor expertise. Agency officials recognize that neither FAA nor Raytheon has the necessary expertise to resolve WAAS technical problems. As noted earlier, FAA has formed a panel of experts to develop solutions to WAAS technical problems. FAA is specifically concerned about Raytheon's level of expertise for refining safety algorithms and assessing the safety of WAAS components. Raytheon acknowledges that this has been a concern and noted that today's tight labor market for high tech skills has exacerbated problems.

According to FAA, it is not necessarily a question of the number of personnel working on the WAAS contract (about 190) but rather the skill mix. FAA and Raytheon officials believe that safety skills—the ability to conduct analyses of the many WAAS subsystems and assess impacts on various phases of flight—are now paramount. FAA officials told us that the skills required are more related to certifying an aircraft like the Boeing 777 (i.e., a "complex system of systems") than a traditional FAA acquisition. Raytheon officials told us that they are taking steps to address the skill mix of Raytheon's WAAS staff, including acquiring personnel from other firms and academia.

Mr. Chairman, that concludes my statement. I would be happy to answer any questions you or other Subcommittee members might have.