Office of Inspector General

Testimony on Observations on the Federal Aviation Administration's Plan to Use Satellite Technology For Air Traffic Management

Report Number AV-1998-001
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U.S. Department of Transportation

Office of the Secretary of Transportation

Office of Inspector General

Memorandum

Subject: INFORMATION: Testimony on Observations on The Federal Aviation Administration's Plan to Use Satellite Technology for Air Traffic Management
Report No. AV-1998-001

Date: October 17, 1997

From: Kenneth M. Mead
Inspector General

Reply to Attn of: JA-1

To: The Secretary
Thru: The Deputy Secretary

On October 1, 1997, at a hearing of the Subcommittee on Aviation, Committee on Transportation and Infrastructure, U.S. House of Representatives, I provided our observations on the Federal Aviation Administration's (FAA) plan to use satellite technology for air traffic management. A copy of our statement is attached for your information.

The Office of Inspector General (OIG) recommended that FAA develop a comprehensive, agreed upon, lucid plan and strategy for transitioning to satellite technology for air traffic management. We recommended the plan address (1) what systems, components, and avionics are required, (2) when they are required, (3) how much they will cost and when the funding is required, and (4) what costs aircraft operators and airports will be expected to cover.

Regarding the presentation of costs for the Wide Area Augmentation System, we noted in our testimony that at least three different estimating methodologies were used in the past. Acquisition costs were generally used to refer to only the prime contract costs. Program costs represented all costs to develop and deploy the system through 2001. Life-cycle costs included acquisition, program, and operations and maintenance costs through the system's useful life, currently planned for 2016. We recommend the FAA use a consistent methodology that includes life-cycle costs and clearly delineates which costs, or range of costs, are attributable to each cost element.

We are concerned that none of the three cost estimating methodologies fully reflect the costs of communications satellites. Our work suggests the range of costs associated with acquisition of communications satellites is between $550 million and $1.3 billion, depending on the number of satellites needed and the manner in which they are acquired. Accordingly, we also recommend that FAA ensure that complete cost estimates for communications satellites are developed and included in the future cost estimates for the Wide Area Augmentation System.

In addition, we identified four issues relating to satellites that need resolution to successfully implement satellite technology. These issues relate to the availability and use of a second Global Positioning System signal, the number of communications satellites needed and how to obtain them, the ability to receive satellite signals adequate for civil aviation when solar activity is at its peak, and the ability to adequately secure Global Positioning System signals from intentional interference.

Before the hearing, I discussed our observations with the FAA Administrator. She concurred that a comprehensive plan for transition to satellite-based systems is needed, and that four issues relating to satellites need resolution.

The OIG will continue to monitor FAA's efforts to transition to satellite technology. We are currently reviewing FAA's communication satellite plans and cost estimates. We intend to review the Wide Area Augmentation System development schedule and FAA's plans for decommissioning ground-based systems, and will keep you informed of our progress and results.

If I can answer any questions or be of any further assistance, please call me on x61959 or Lawrence H. Weintrob, Assistant Inspector General for Auditing, on x61992.

Attachment

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cc: Federal Aviation Administrator

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

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

Observations on the Federal Aviation Administration's Plan to Use Satellite Technology for Air Traffic Management

Statement of Kenneth M. Mead
Inspector General
U.S. Department of Transportation

Mr. Chairman and Members of the Subcommittee:

We appreciate the opportunity to provide our views on the Federal Aviation Administration's (FAA) Wide Area Augmentation System, commonly referred to as WAAS.

In June 1995, I testified before the Committee for the GAO about FAA's efforts to augment the Global Positioning System for use in civil aviation navigation. At that time, it was noted that FAA's schedule to implement WAAS by 1997 was ambitious and could be slowed by potential difficulties--some of which were beyond FAA's control. Since then, the implementation date has slipped. FAA expects to have initial WAAS operational capability available for use in 1999 with pilots being able to use WAAS as the primary means of navigation in 2001.

Our testimony today will first address the need for FAA to complete a comprehensive, agreed upon, lucid plan and strategy for transitioning to satellite technology for communications, navigation, and surveillance. Transitioning to satellite-based technology involves numerous systems that must work together in order to optimize benefits. FAA's comprehensive plan must, therefore, integrate individual system or organizational specific plans that currently exist. The plan should address:

1) what systems, components, and avionics are required;
2) when they are required;
3) how much they will cost and when is the funding required; and
4) what costs will aircraft operators and airports be expected to cover.

We also will address four issues relating to satellites that need resolution in order to successfully implement satellite-based systems. These issues relate to the availability and use of a second Global Positioning System signal, the number of communications satellites needed and whether to lease or purchase them, the ability to receive satellite signals adequate for civil aviation when solar activity is at its peak, and the ability to adequately secure Global Positioning System signals from intentional interference. The resolution of these issues will have an impact on when, and to what extent, FAA will be able to decommission its ground infrastructure. Decommissioning also assumes that air carriers and general aviation will be equipped with satellite avionics by the decommissioning date.

We have discussed these matters with FAA and the new FAA Administrator. The Administrator concurs on the need for a clear, agreed upon, comprehensive action plan for implementing satellite systems. FAA has already taken steps to begin formulating a comprehensive plan. FAA's revised National Airspace System (NAS) Architecture for modernizing the system is expected to be issued in December 1997. This Architecture can serve as a plan and provide a good foundation for a successful transition to satellite technology if it includes the four areas described above. The usefulness and credibility of this plan, however, will depend on FAA's ability to achieve a consensus. It is of critical importance that the plan, including any modifications, reflect consensus by FAA and the Congress as well as the users and the aviation industry.

Before discussing the importance of this plan and the satellite issues that need resolution, we would like to explain the benefits expected from the transition to satellite technology. We would also like to describe the role WAAS plays in this transition.

The use of satellite technology offers the aviation industry and FAA capabilities that go beyond those of today's ground-based systems. Direct routing of aircraft, with associated fuel economies, a significant increase in air traffic capacity and safer precision landing capabilities at airports that do not have precision landing systems today, are possible when satellite technology is used for aviation navigation, communications, and surveillance functions.

The use of the Global Positioning System, communication satellites and advanced decision support systems will allow pilots, in a collaborative effort with controllers, to chart their most efficient course. These systems will also add a higher degree of precision, with regard to position, speed, and direction, which is needed to safely reduce separation between aircraft. Satellite-based systems will move us from air traffic controlled by controllers, to air traffic more efficiently managed by controllers, pilots, and air carriers. All of this must be accomplished within parameters that assure safety, affordability to FAA and users, and meet very stringent requirements for accuracy, integrity, availability, and continuity of service.

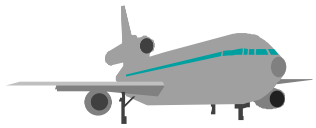
It is important to recognize that WAAS, a project with a life-cycle cost of $2.4 billion, is but one of numerous systems that needs to be developed and deployed to effectively transition to satellite-based technology and fully achieve the anticipated benefits. WAAS, as currently envisioned, provides enroute navigation capability that offers direct routing. WAAS is expected to support Category I[1] precision approaches at airports including those where precision landing systems currently do not exist. WAAS does not provide precision approach and landing capability equivalent to Category II and III. Also, without new communication and surveillance systems, WAAS will not in itself provide the full benefits of increased airspace capacity and efficient routing.

<u>FAA Needs to Complete a Comprehensive Plan to Transition to Satellite-Based Communications, Navigation, and Surveillance</u>

The transition to satellite-based communications, navigation, and surveillance systems is intended to ultimately result in the implementation of the "Free Flight" concept. This concept does not mean pilots can fly anywhere they want, when they want. However, the concept does envision that pilots will be allowed to fly user preferred routes, providing they can do so safely, given air traffic and airport capacity constraints. "Free Flight" will change air traffic control to air traffic management. Under the "Free Flight" concept, pilots will collaborate with air traffic managers, and restrictions on pilots will only be imposed to ensure safety.

To achieve the benefits of "Free Flight" as contemplated by FAA and industry, new communication, navigation and surveillance systems, including WAAS, will be needed. Issues such as identifying all the components needed for the systems, when they are needed, how much they will cost, and how they will be paid for needs to be fully developed and agreed upon. The following chart identifies the key capabilities needed for "Free Flight."

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



Key Capabilities to Achieving Free Flight

- COMMUNICATION (Data Link)
- NAVIGATION (WAAS/LAAS)
- SURVEILLANCE (ADS-B)
- DECISION SUPPORT (Cockpit Information, Traffic Flow Management, Conflict Probe)

SYSTEMS-PROCEDURES-CERTIFICATION

- Data Link will provide enhanced communications, in a digital format, to pilots and air traffic managers. That format will allow significantly more data to be communicated.

- WAAS will provide the capability to navigate in the en route environment and allow precision approaches at more airports under certain conditions.

- Local Area Augmentation System (LAAS) will allow precision landing at additional airports under more severe conditions.

- Automatic Dependent Surveillance-Broadcast (ADS-B) will use GPS satellites to identify aircraft, their speed, location and direction, and provide this information to users of the system.

- Decision support systems, such as Conflict Probe, which will alert air traffic managers and pilots when aircraft are projected to be too close to each other.

Each of the systems shown on the previous chart must be developed, acquired, and deployed. Procedures must be written to use each system, and the systems (hardware, software, and procedures) must be certified as safe. These actions require three organizations in FAA to work together - - Research and Acquisitions, Air Traffic Services, and Regulations and Certification.

In August 1996, RTCA, Inc., published a “joint government/industry” “Free Flight” action plan. RTCA’s plan lays out by timeframes and what needs to be done. The plan does not identify funding requirements or indicate who will pay for what.

The RTCA plan reflects a collaborative effort between FAA representatives and industry. In January 1997, FAA requested that RTCA form a new committee to work with the FAA to develop the next version of the NAS Architecture. This committee is expected to help FAA ensure that their revised architecture represents a consensus of airspace users, the aviation industry, and the FAA. The next version for the NAS Architecture is expected to be issued in December 1997. In order to be useful and credible, this plan must identify what systems, components, and avionics are required, and when they are required. It must also include an estimate of how much they will cost, when funding is required; and who will pay for what (FAA, users, airports). Most important, for this plan to be realistic, this plan and any needed modifications to it, will need a consensus by the Congress, FAA, and the aviation community.

FAA Needs Cost Estimates and a Financing Plan

Financing must be an important element of the overall strategy and plan for implementing satellite-based systems. Both FAA and the aviation community will incur significant costs to transition to satellite-based systems and “Free Flight.” Currently, an estimate of total potential costs to either does not exist and there are several uncertainties about who will pay for what. These uncertainties extend not only to who will pay for onboard aircraft equipment associated with Flight 2000 and “Free Flight,” but also to LAAS equipment which will be located at or near airports. A consensus is needed to resolve these uncertainties.

We computed, by adding up estimates on various FAA documents, FAA’s total estimated costs to switch to state-of-the-art technologies, including, but not limited to, satellites. The estimated costs were $13.5 billion. The FAA documents from which we extracted the various cost estimates covered different time periods ranging from the next 6 years to the next 19 years. Collectively, they appear to be “at least” numbers since some did not reflect full life-cycle costs. Of the $13.5 billion we identified, $6 billion is for communications, $4.1 billion for navigation, and $3.4 billion for surveillance equipment and systems. We could not determine how much of the $13.5 billion was specifically for satellite related technology. WAAS life-cycle costs were $2.4 billion through 2016. The plans reviewed did not contain life-cycle cost estimates for other programs such as Aeronautical Data-Link, Automatic Dependent Surveillance-Broadcast, or LAAS.

LAAS, intended to complement WAAS, will broadcast navigation information in a “localized” service area. This area would typically encompass a specific airport or airports within close proximity. LAAS should be able to provide pilots with precision-approach service including all Category I, II, and III minimums. FAA expects to spend $23.2 million for a prototype system of LAAS through 2001. The $23.2 million will be used to begin development of the functional specification based on the selected LAAS architecture and compatible avionics. The $23.2 million does not include life-cycle costs to acquire systems beyond the prototype and to operate and maintain the system.

Even when life-cycle costs were included in FAA estimates, the estimates did not reflect all potential costs. For example, FAA's $2.4 billion life-cycle cost for WAAS included $957.8 million for acquisition of the system. This acquisition cost included $85.7 million for communications satellites. However, as we will discuss later, FAA has not made a decision regarding the acquisition strategies it will use to fulfill its satellite requirements. That final decision may have an impact on WAAS costs.

The WAAS acquisition costs, as currently estimated, do not include costs of modifications which may be necessary to utilize a second Global Positioning System signal. That cost has been estimated at $35 million. However, acquisition of a second signal could also result in significant cost reductions for FAA's ground reference stations. Where decisions which have a consequential effect on the life-cycle cost of a program have yet to be made, FAA's plan should identify the various options and the probable funding impact of each.

We reviewed WAAS program documents spanning the period April 1994 to July 1997. We found that FAA did not use a consistent method for cost estimating. An April 1994 cost benefit analysis for WAAS reflected an estimated total life-cycle cost through the year 2014 at $1.4 billion. Program documentation in July 1997, reflects an estimate of total life-cycle costs for WAAS, through the year 2016, at over $2.4 billion. Our analysis of this showed that FAA has been slow to fully recognize all life-cycle costs of systems.

FAA's new Acquisition Management System requires FAA managers to identify all costs to acquire, operate, and maintain new systems throughout their useful life. Until recently, WAAS documentation generally excluded operation and maintenance costs.

In our opinion, FAA's efforts to include life-cycle cost estimates for all satellite related systems and supporting activities will establish an understanding of the financial requirements and greatly facilitate decision making. Once established, these projected life-cycle costs should be integrated into FAA's plan to ensure effective transition to the new technologies.

Several issues about who will pay certain of the costs to implement satellite technologies have not been resolved. Traditionally, FAA has paid for the ground-based air traffic control equipment, both enroute and at airports, needed for communication, navigation, and surveillance. Aircraft owners and operators have paid for the on-board avionics needed to use the ground-based systems. In its October 1996 National Airspace Architecture, FAA indicated that owners and operators should share in the costs of modernizing the National Airspace System. However, what this sharing concept will entail is uncertain. For example, according to the Flight 2000 program office, FAA will pay approximately $170 million to equip aircraft with avionics for this demonstration program. While Flight 2000 is very similar to "Free Flight," it is not clear what, if any, of the cost will be shared. Resolving these financing decisions is important as aircraft equipment costs can be considerable. A similar issue surrounds the question of who will pay for LAAS equipment at or near airports.

Key Issues Related to Satellite Usage

In order for satellites to be relied upon and achieve their intended benefit, it is critical that they provide the high degree of accuracy, integrity, availability, and continuity of service needed for civil aviation.

Mr. Chairman, we would like to highlight four satellite-related issues which bear upon the ability of satellites to fully meet these requirements. The resolution of these issues will help determine whether (1) ground-based systems will be retained, and (2) the equipment purchased by users to support satellite-based systems may need to be replaced prematurely. The issues concern the following:

- Availability and use of a second Global Positioning System signal.
- Number of communications satellites needed and whether to lease or purchase them.
- Ability to receive satellite signals adequate for civil aviation when solar activity is at its peak.
- Ability to adequately secure the Global Positioning System signal from intentional interference.

Decision Needed on Availability of Second Global Positioning System Signal

The Global Positioning System satellites currently provide information via two signals. These signals are referred to as L1 and L2. The L1 signal is not encrypted and provides information to any user worldwide. The L2 signal is more precise than the L1 signal, is encrypted, and is restricted for U.S. military and national security uses.

The White House Commission on Aviation Safety and Security in February 1997, recommended developing an additional frequency in the next generation of Global Positioning System satellites. The availability of a second signal is important because it would allow distortions to the signal to be calculated and corrected aboard the aircraft rather than by a ground station. If there is only one signal, that signal must pass through a ground station to make necessary adjustments and the corrected data are sent to the aircraft through communication satellites. FAA currently estimates that if a second signal became available, the number of ground reference stations needed for WAAS could be reduced. The reduction could be as many as 27 stations, resulting in cost savings of as much as $159 million.

According to industry experts, delaying the decision on access to a second signal will have a direct impact on the avionics and related equipment for aircraft. The concern is that if this decision is not made soon, commercial aircraft owners and operators will purchase avionics equipment capable of processing only the L1 signal. This equipment may not be able to receive the additional signal, and the aviation industry would have to pay to modify its aircraft or purchase additional avionics to use the second signal.

Decisions Needed on Satellite Requirements

In order to reduce acquisition costs, WAAS as currently planned, will use leased communication satellites to transmit the Global Positioning System data. These leased satellites are expected to have other higher priority commercial users. Under these circumstances, FAA's signal could get "bumped" in favor of higher priority users. If that happens, navigation data sent to aircraft could be interrupted or disconnected. This creates a potential safety problem for aircraft that do not have back-up systems.

FAA is currently re-examining its plans for obtaining the use of satellites for WAAS. Three options are under consideration. The first is the existing plan which envisions leasing seven to nine satellites on which FAA would not have dedicated use. The second envisions FAA leasing four to five dedicated satellites. The third envisions FAA purchasing four to five dedicated satellites. This decision will have implications on the cost of FAA's program.

FAA recognizes this issue and is consulting with the Department of Defense to determine how best to proceed to meet its satellite needs. Unless decisions are made soon, however, FAA's ability to implement WAAS as scheduled in 2001 may not be met because a lead-time of about 4 years is typically necessary to purchase, launch, tune, test, and turn on a satellite.

<u>Impact of Solar Activity Needs to be Determined</u>

As the signals from Global Positioning System satellites travel from the satellite to the airplane and to the ground reference station, the signals pass through the earth's ionosphere. The ionosphere is a blanket of electrically charged particles about 80 to 120 miles above the earth. As the Global Positioning System signals pass through the ionosphere, they are bent and twisted and the transmission of the signal is slowed. This results in errors in the information provided by the signal. Predicting the full extent of ionospheric distortion to the signal is crucial in determining how to compensate for it. Determining the potential distortions associated with the signals passing through the ionosphere would not be a problem if ionospheric conditions were constant. Unfortunately, they are not, and there is little historical data from which to model the problem and develop a solution.

The composition of the ionosphere varies with the cycles of the sun. The sun goes through an approximate 11-year cycle of activity. The period of the heightened activity is termed the solar maximum. The highest energy output from the sun occurs at this time.

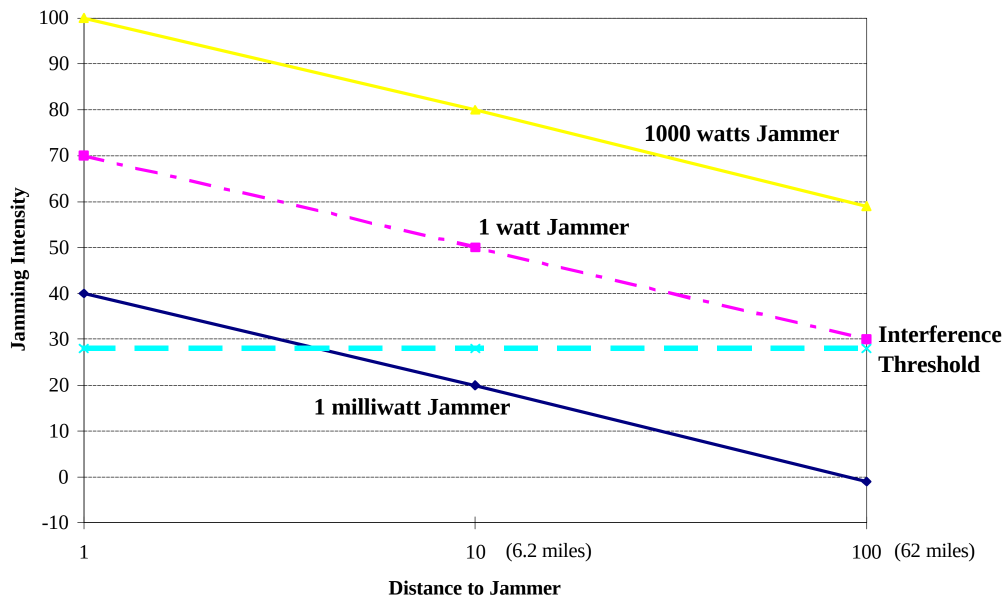
The next solar maximum is expected to occur in the year 2000. It is expected to last about 14 to 16 months. Until this event occurs and data are gathered, neither FAA nor industry can predict with certainty the impact of the solar maximum on the Global Positioning System signal. If it is determined that the "solar maximum" impairs Global Positioning System signals, FAA will either have to find a compensating solution using satellite technology or maintain a backup system.

<u>Security of Satellite Signals Must be Resolved</u>

In order to use satellites for civil aviation without a ground-based backup system, the system must meet FAA's stringent requirements for accuracy, integrity, and continuity of service. This is especially important during precision landings when accuracy requirements are the greatest. To achieve this, the signal from the satellite must be protected from intentional interference, referred to as "spoofing" or "jamming." Spoofing is an attempt to fool a receiver into using a false signal instead of the actual Global Positioning System signal. Because this method of interference is highly sophisticated and technologically challenging, it is not as great a risk as jamming. Jamming is an intentional attempt to interfere with signal reception. Jamming involves using radio transmitting device to interfere with the Global Positioning System signal.

The Global Positioning System signal used for civil aviation purposes is the signal available to the public (L1). The Mitre Corporation reviewed the vulnerability of the L1 Global Positioning System signal to intentional interference. We analyzed the information they developed and prepared the following simplified chart to show how a jamming device can effectively prevent a receiver from acquiring an accurate signal.

Line-of-Sight
GPS SIGNAL INTERFERENCE



The horizontal axis represents the distance between the jammer and the typical Global Positioning System receiver in kilometers. The vertical axis represents the jammer interference to the Global Positioning System signal in decibels (dB) or the jamming intensity. The three diagonal parallel lines represent three jamming devices with different effective power measured in watts and milliwatts.

For example, a jammer with 1 watt of effective power can cause interference of almost 30 decibels to a Global Positioning System receiver located at 62 miles (100 km) away. A 1,000 watt (1 kilowatt) jammer can cause interference of almost 60 decibels when placed at the same distance from the Global Positioning System receiver.

All the values plotted above the broken horizontal line (Interference Threshold) indicate that the Global Positioning System receiver can be jammed at the corresponding distances and jamming intensity. The values plotted below the dotted line, represent the range of optimal operation for the receiver, i.e., without interference by a jamming device.

The data developed by Mitre lends credence to reports that the British have demonstrated that a 1-watt weather balloon transmitter could disrupt the Global Positioning System signal for 30 miles in any direction. The Mitre data also adds concerns about a Russian company (Aviaconversia) marketing a device which it claims can block the Global Positioning System and the Russian Federation's Glonass signals at ranges of 200 kilometers. The Federal Communications Commission can impose fines and prison time of up to 20 years for jamming any communications or navigation aid signal. This may be a deterrent, but not a solution to the problem. FAA knows it must be certain that it can adequately protect satellite signals before it decommissions ground-based systems. FAA is aware of these issues and is now performing risk mitigation analysis to identify appropriate counter measures.

Mr. Chairman, this concludes our statement. I would be pleased to answer questions.