

WIDE AREA AUGMENTATION SYSTEM (WAAS)

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Abstract

Global Positioning System (GPS) navigation signals alone are not adequate to support aviation navigation. GPS accuracy is acceptable for all but precision approach applications, but integrity, continuity, and availability are lacking. Wide Area Augmentation System (WAAS) hardware has been installed and used for testing since last summer. Wide Area Reference Stations receive GPS signals and forward them to Wide Area Master Stations for corrections processing. Augmentation messages are sent to the Ground Uplink Stations for transmission to Geosynchronous (GEO) satellites that retransmit the messages to avionics receivers in aircraft. WAAS is a safety critical system, meaning time to alarm is critical and transmission of hazardously misleading information is not allowed. Phase 1 WAAS will be commissioned in September of next year and will provide enroute through non-precision approach services throughout the US Flight Information Region. Precision approach services will be provided over roughly 50% of the continental US. END-state WAAS will provide CAT-I precision approach navigation service throughout the continental US.

The key to all WAAS operations is time. The GPS satellites, the GEO satellites, and all WAAS hardware suites must agree upon time. Precision time has been identified as one of the major untapped byproducts of WAAS.

AT THE DAWN OF A NEW SPACE AGE ...

Travelers once relied upon the stars for guidance. In the next millennium, the heavens will again transform the art of navigation.

Since the US FAA opted to establish a satellite-based navigation capability, no one has needed a dictionary to define "augmentation." It refers to the greater accuracy with which US flights will determine their coordinates, both enroute and during final approach, using a nationwide ground infrastructure to calculate and broadcast corrections to the GPS positioning signal.

Differential correction is a simple principle that belies the sophistication of the FAA's Wide Area Augmentation System. This is because GPS needs not only to be accurate; it needs to be available, and to warn users when it won't be.

Key to WAAS is signal integrity, which the FAA will evaluate next year, leading to Initial Operating Capability in the autumn of 2000.

As prime contractor for WAAS, Raytheon has installed 25 ground reference stations to collect and forward GPS data and two master stations to calculate corrections and uplink the information to two geostationary Inmarsat satellites - which then relay these augmented data to aircraft.

During critical 72-hour signal-in-space tests in April 1999, the FAA showed WAAS could determine positions to within three to five meters - some 20 to 30 times better than the GPS signal. Four months later the system passed an eight-day stability test - during which the FAA even took advantage of the opportunity to conduct unscheduled trial approaches.

As well as increasing capacity - by allowing safe reduction in separation - enabling more direct flight paths, and reducing reliance on ground-based nav aids, WAAS will provide Category I precision-approach accuracy across some 50% of the US - mainly the central region - when the first phase becomes operational.

PRESENT PLANS

Today, WAAS is undergoing system acceptance testing. Following completion of analytic studies of these test results, the FAA will accept system ownership in the spring of 2000 and begin certification testing. Once certification testing is complete, the system can be placed into operation.

WAAS's multi-phase six-year contract has undergone changes during the past year. Phases 2 and 3 have been replaced with a multi-year, incrementally funded agreement that will result in modifications to the software, additional ground stations, and eventually, new system hardware. The present system hardware was first identified and purchased four years ago, and will have aged ten years when the effort is complete, making maintenance more difficult.

As new reference stations are added, the ability to achieve Category I precision approach navigation services throughout the US will be realized. New hardware will also allow reference stations to be located in Canada, Mexico, the Caribbean, and in Iceland, creating North American WAAS. Similar, but more modest efforts in South America will provide an enroute through non-precision approach navigation service for that continent as well.

The most expensive addition to WAAS will be adding more geostationary satellites. The present two satellites provide only limited overlapping coverage in North America, making the system vulnerable to satellite failure. Three additional geostationary satellites, appropriately placed, will finally give the system the robustness for which it was designed.

WAAS PROCESSING

The WAAS reference stations report all GPS observations to the master stations over two independent communications networks. The master stations process the received data in two independent computers and compare the derived corrections, ensuring only correct, consistent, reliable information is transmitted to the users. If inconsistencies are detected or unreasonable answers derived, the data are flagged as erroneous and not for use. One of WAAS's principal missions is safety processing, ensuring there is no hazardously misleading information (information that appears to be correct, but is not) sent to users, and if things are not right, everyone knows of the errors within a few seconds (short time to alarm).

WAAS goes to great lengths keeping all its clocks synchronized with GPS. As with all GPS processing, time is the key ingredient. WAAS removes the selective availability imposed GPS timing errors in a process known as "fast corrections." The next error source, poor knowledge of the exact location for each of the satellites, is then corrected. All satellites naturally "drift" from their theoretical position in orbit. During ground-controlled orbit maintenance periods, the "drift" can be dramatic. WAAS uses a less frequently executed process called "long-term corrections". Finally, the distortions of the signal in the atmosphere, especially in the ionosphere, are determined, and appropriate corrections derived. These ionospheric corrections are vital in achieving accuracy measurements less than 7.6m for Category I precision approach navigation services.

All of these correction values are transmitted to a geosynchronous satellite that immediately rebroadcasts the data back to earth and the user receivers at the same time and on the same frequency as the GPS broadcast. The user receivers use GPS to derive a basic navigation "fix" and then correct that fix using WAAS data.

The WAAS corrected solutions are not only more accurate than GPS alone, but the integrity, continuity, and overall availability of the GPS navigation signal have been improved.

SOLE-MEANS WAAS

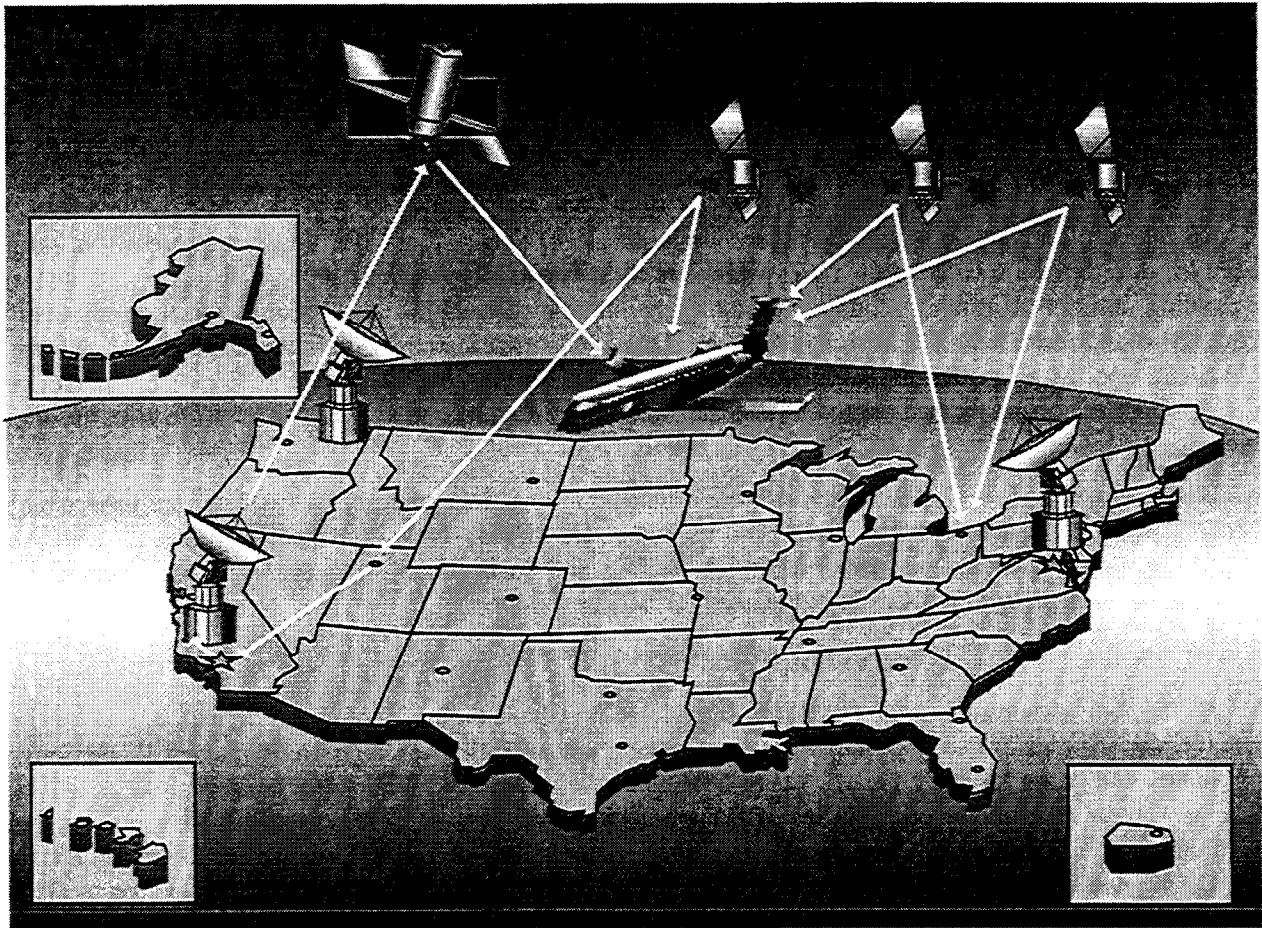
WAAS takes full advantage of the fact there are in excess of twenty-four GPS satellites presently in orbit, twenty-five reference stations growing to well over fifty, two master stations growing to up to six, and an expanding number of ground uplink stations to generate and process far more information than minimally required to support a navigation signal service. This robustness materially aids the objective of allowing WAAS to operate as a sole-means navigation service. Sole-means facilitates cost savings from no longer maintaining the present extensive ground-based navaid infrastructure, and allows all aircraft to simplify their on-board avionics.

Reliance upon WAAS for sole-means navigation will be a long time coming. WAAS will be proven only through practical, in the field experience with its navigation signal. Only after demonstrating its ability to reliably maintain its signal in space during all weather and solar conditions will the aviation community slowly began accepting WAAS without the need for backup systems.

AN ENABLING TECHNOLOGY

WAAS is also important as an enabling technology for the next millennium's international air traffic management systems. These systems will fundamentally change the way airspace is managed. No longer will radars and ground-based air traffic controllers be the key elements. While radars and controllers will not disappear, their roles and responsibilities will change. Pilots will become more responsible for reporting their positions to all in their vicinity and in avoiding air traffic conflicts. It will be possible for more airplanes to use the limited available airspace than now possible. More direct routing between destinations will be possible, and quicker recoveries from weather-induced delays will be commonplace. Today our US national air traffic control system is being driven to its knees by the heavy air transportation load imposed. New processes and procedures based at least partially upon WAAS are the beginning of the solution.

WAAS truly is a key technology as we face a new space age ...



Wide Area Augmentation System (WAAS). All WAAS sites have been installed for over a year. The system software is presently undergoing system acceptance testing. FAA certification is expected to be completed by September 2000 and the system placed into operation.

<u>WAAS Navigation Services</u>	<u>WAAS Operational Improvements</u>
Enroute through non-precision approach navigation services throughout the US	Dramatically improved flight safety due to vertical guidance for <u>all</u> landings
Category I precision approach navigation service over roughly 50% of the central US	An enabling technology for implementing advanced flight procedures that will make the National Airspace System (NAS) more efficient

Phase 1 WAAS provides navigation services that dramatically improve flight safety while improving the FAA's National Airspace System's efficiency.

Questions and Answers

VICTOR REINHARDT (Hughes): Do you need a full geosatellite or do you just need a payload on board the satellite? I mean, is the payload –

DONALD ORMAND (Raytheon): All I need is that transponder.

REINHARDT: So you can use existing transponders?

ORMAND: The transponders that we need that require absolutely no change on our part; just something that will take a C-band input and turn it into an L-1 going out.

REINHARDT: Okay, so you need a special transponder then on another bird, if you could do it that way? You'll need a special L-1 type transponder.

ORMAND: Yes, it's got to be an L-1 transponder like that.

ED BUTTERLINE (Symmetricom): Did I understand you to say that your 25 reference stations are interconnected by two physically diverse communications networks that have no connectivity or commonality with national telecommunications networks?

ORMAND: Well, what I was trying to say is that it's an independent thing. Its links is part of the FAA. The FAA uses other link networks, but it's a dedicated set of networks for us.

BUTTERLINE: The key point that caught my ear was no commonality with national telecommunications networks. You might buy a network from Brand A and another network from Brand B and think you're physically diverse. You're very naive. Contrary to how they advertise, carriers interchange facilities rather easily and frequently, and if you have any commonality with telecommunications networks, I question whether your diversity is what you think it is.

ORMAND: It would not be the first time I have been accused of being naive.

DAVID ALLAN (Allan's Time): A question on the ionosphere. Should the ionosphere, for example, double over the course of the next year, the fluctuations, of course, also increase; how does that impact the accuracy specification on, say, Category 3?

ORMAND: If I understood the question, it's really when we have violent storms and the thing gets back, how does that affect the accuracy. God knows, I don't know. We're going to end up finding out here in the next 2 or 3 years exactly what that is. In the old days, a lot of the receivers would lose lock during these ionospheric disturbances. Today, we've got nice NovAtel receivers and everybody else and they don't lose lock. I mean, they can, but they typically don't. And everything that we've seen in the last few years through all the solar disturbances, the receivers have maintained lock. And if they do that, we've got a fighting chance then to do the calculations.

I can't answer the question because I don't know the answer to that. But like I say, in the old days the issue was actually losing lock. And we're not doing that anymore.