

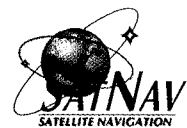


FAA Satellite Navigation Program Master Plan

FY 1995 - 2000



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**Federal Aviation Administration
Satellite Program Office (AND-510)
Research and Acquisitions**

August 31, 1995

Operational Summary

The overall objective of this Satellite Navigation Program Master Plan is to support the operational use of satellite navigation for all civil aviation needs.

The program outlined in this plan contributes to this overall objective by developing and testing the feasibility of various satellite navigation techniques; developing and implementing a Wide Area Augmentation System (WAAS) and a Local Area Augmentation System (LAAS) for the Global Positioning System (GPS); and supporting the development of operational procedures and standards to satisfy civil aviation requirements for all phases of flight.

A summary chart outlining the projected operational implementation schedule based on GPS services is provided for initial reference. The subsequent program plan provides additional information and supports the milestones indicated on this summary chart.

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Projected Operational Implementation Dates

	Calendar Year	91	92	93	94	95	96	97	98	99	00
Oceanic En Route		○		√	□						
Domestic En Route		○		√					□		
Terminal				√					□		
Non-Precision Approach				√					□		
Cat I Precision Approach						⊙			√		
Cat II/III Precision Approach							◇				
GPS Input to Multisensor Nav		○									
GPS as Supplemental Nav				√							
GPS as Primary Nav									□		
Special Cat I						⊙					
Feasibility Determined										◇	

GPS as Input to Multisensor Navigation. A GPS receiver can be used in conjunction with another navigation aid that is already approved for that phase of flight. The other navigation aid must be operational and functioning at all times. Example: A GPS receiver and an IFR-approved VOR receiver are both operating and the GPS position is constantly cross-checked with the position derived from the VOR.

GPS as Supplemental Navigation. A GPS receiver that is TSO approved can be used in controlled airspace of the National Airspace System (NAS) in conjunction with a primary means of navigation.

GPS as Primary Navigation. A GPS receiver capable of meeting the performance specified for operation within a defined airspace, i.e., Required Navigation Performance, without reliance on any other navigation system onboard the aircraft.

GPS as Augmented for Special CAT I. The FAA will provide an operational specification approval to users on a case-by-case basis for a precision approach capability. All equipment required will be purchased by the user, not the government.

Feasibility Determined. The FAA will determine technical, operational, and institutional feasibility of using GPS for Category II/III precision approaches.

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SATELLITE NAVIGATION PROGRAM MASTER PLAN

INTRODUCTION

Purpose

The Satellite Navigation Program Master Plan presents the needs, scope, objectives, and other requisite planning information for the Federal Aviation Administration's (FAA) Satellite Navigation Program for the period from fiscal year 1995 through fiscal year 2000. The purpose of this plan is to (1) provide an opportunity for review and approval of the Satellite Navigation Program; (2) describe FAA satellite navigation research, development, and acquisition activities for all interested civil aviation organizations; and (3) provide schedules for civil augmentation and operational implementation of the Global Positioning System (GPS) in the National Airspace System (NAS).

The plan contains an executive overview of the overall program and supporting program efforts, GPS and Global Orbiting Navigation Satellite System (GLONASS) descriptions (Appendices A and B, respectively), descriptions of the individual projects and subprojects comprising the overall program (Appendix C), program milestones (Appendix D), Program Manager's Charter (Appendix E), a list of critical satellite navigation milestones already achieved (Appendix F), and a list of acronyms used in the plan (Appendix G).

Statement of Need

Satellite navigation presents opportunities for standardized worldwide civil aviation operations using a common navigation receiver and for significant improvements in safety, capacity, service flexibility, and operating costs. Adoption of satellite navigation systems will most likely lead to the eventual phaseout of existing NAS ground equipment while maintaining or improving existing levels of service. In addition, satellite-based navigation systems provide the potential for new navigation and landing services not currently supported by existing systems.

Satellite navigation potential and opportunities have prompted the aviation industry to begin producing satellite navigation receivers, and aviation users are demanding operational guidance for their use. However, satellite navigation systems, specifically GPS, have not been designed solely for civil aviation use. Aviation requirements, such as system integrity and accuracy, must be thoroughly investigated and satisfied prior to permitting operational use. Additionally, a sound transition plan, with supporting Minimum Operational Performance Standards (MOPS), Terminal Instrument Procedures (TERPS), Technical Standard Order (TSO) procedures, certification criteria, and air traffic procedures must be developed to ensure a smooth transition from today's technology and procedures to tomorrow's satellite-based navigation systems.

SATELLITE NAVIGATION PROGRAM OBJECTIVES

The overall objective of the FAA's Satellite Navigation Program is to support the operational use of satellite navigation for all civil aviation needs in oceanic, en route, terminal, nonprecision approach, precision approach, auto-landing, and departure operations.

BENEFITS

The aggressive, early exploitation of satellite navigation technology provides substantial benefits in meeting a number of FAA and aviation user goals:

- Consolidation of navigation functions into a single satellite-based system thereby enabling the eventual phaseout of older navigation aids at substantial savings.
- Improved safety with reduced separation minimums resulting in increased system capacity and capabilities.
- More flexibility to implement accurate area navigation by using efficient, optimized, user-preferred flight paths.
- Significant reductions in aircraft operating costs through the use of efficient route structures.
- Accurate position reporting to enable uniform high-quality, worldwide air traffic management (ATM).
- Improved ground and cockpit situational awareness to reduce runway incursion.
- Increased landing capacity with up to Category I precision approach service to all runways and airports for all aircraft types -- including helicopters.
- Category II/III precision approach services.

BACKGROUND

The potential application of satellites in the future aviation system has been the subject of numerous studies for more than 25 years. However, early efforts to promote satellites for civil aviation were constrained by the high initial costs associated with the research, development, and establishment of a satellite constellation large enough to support civil aviation needs. In addition, the high cost of satellite navigation receivers relative to alternative ground-based system receivers further inhibited the introduction of a satellite-based system.

These obstacles have been largely overcome, however, as a result of the development and deployment of GPS by the Department of Defense (DoD). (A description of GPS is contained in Appendix A.) Advances in digital technology and the already large civil GPS user base offer the promise of cost-competitive avionics with capabilities and performance that surpass those available from ground-based systems.

The FAA's Satellite Navigation Program has been established to capitalize on these advancements and to respond to the civil aviation users' navigation requirements for worldwide availability/continuity of service, accuracy, and integrity.

The FAA, with the International Civil Aviation Organization (ICAO) and other members of the civil aviation community, has recognized that the primary stand-alone navigation system in the 21st Century will be provided by a Global Navigation Satellite System (GNSS). Following a Communications/Operations Divisional meeting convened in March 1995, ICAO validated the use of GNSS with augmentations to support approaches and departures including CAT I operations. ICAO also endorsed the continuation of feasibility analyses of the suitability of GNSS for precision CAT II/III approach and landings using differential techniques.

GNSS will be an evolving system, building on the initial foundation of available State-provided systems such as the U.S. GPS and the Russian GLONASS. (A description of GLONASS is included in Appendix B.) Later, these initial systems may be augmented with other satellite systems as they become available and are needed to meet increased requirements for availability/continuity of service, accuracy, and integrity.

Late in 1991, at the request of the FAA Administrator, the RTCA, Inc. formed a special task force to formulate a consensus strategy for early implementation of a GNSS capability in the U.S. The task force consisted of volunteers from commercial and general aviation, industry, airports, the DoD, and the FAA. After nine months of study and discussion, the task force reached a solid consensus that the user community wants, needs, and is ready to implement GNSS-based operations to achieve projected benefits in virtually all aspects of civil aviation operations. The task force concluded that the implementation of GNSS represents the greatest opportunity to enhance aviation system capacity, efficiency, and safety since the introduction of radio-based navigation more than 50 years ago. The RTCA task force provided a series of recommendations for expediting the introduction of a GNSS capability. Many of the RTCA recommendations are addressed in this plan for FAA evaluation and implementation.

In November 1992, the General Accounting Office (GAO) completed an assessment of the FAA's precision landing system architecture. The GAO report concluded that satellite technology may have the potential to satisfy some or all of the FAA's precision landing system requirements. The study also recommend a detailed assessment to determine which alternative system, or mix of systems, would provide the most benefits at the lowest cost to both FAA and precision landing system users. The FAA has completed a Precision Landing System Architecture study and initiated a CAT II/III feasibility analysis to assess GPS's ability to satisfy precision landing requirements. The feasibility analysis is scheduled for completion in 1995. At that time, a decision will be made on the most promising alternative to replace existing instrument landing systems.

In June 1993, FAA announced approval of GPS for use as a supplemental navigation aid for en route through nonprecision approach pending declaration of initial operating capability (IOC) of GPS. In February 1994, the FAA Administrator sanctioned use of GPS commensurate with approval of the first GPS receiver certified for flight operation through nonprecision approach. In June 1994, the Requests for Proposals for the WAAS were issued, and proposals were received in the fall of 1994. In September 1994, the FAA published FAA Order 8400.11 which provided criteria for approval of private differential GPS (DGPS) facilities and airborne installations in support of Special Category I (SCAT I) operations. Finally, in December 1994, FAA approved GPS as a primary means of navigation in oceanic and remote areas. (This milestone was achieved approximately six months ahead of the original schedule.) A major milestone was achieved on August 3, 1995, with the award of the WAAS development contract.

PROGRAM STRATEGIES

The FAA Satellite Navigation Program embodies three fundamental, underlying strategies: (1) an initial focus on the GPS, (2) extensive involvement of FAA operational personnel, and (3) early and continued involvement of avionics manufacturers, aviation users, and international civil aviation authorities.

Initial Focus

Since GPS will be a cornerstone of GNSS and is under U.S. Government control, the initial focus of the FAA Satellite Navigation Program is on GPS. As information is made more readily available on additional satellite navigation systems such as GLONASS, the scope of the FAA Satellite Navigation Program will be broadened to include all such systems which may become components of the GNSS.

Active Multiagency Involvement

The FAA Satellite Navigation Program has been structured and is proceeding on a broad, multidisciplinary basis. The Satellite Program Office (AND-510, formerly ARD-70) in the FAA's Integrated Product Team (IPT) for GPS/Navigation provides overall direction and exercises program management responsibility. The management structure features the IPT approach, which includes extensive involvement of FAA Flight Standards, Certification, Air Traffic, and Airways Facilities. The program also relies on the active involvement of representatives of the civil aviation community, DoD, and avionics manufacturers. The objective of involving representatives from other elements of FAA, the civil aviation community, and manufacturers is fourfold:

- to ensure that research and development (R & D) activities are properly focused on addressing user requirements,
- to leverage the extensive activities and expertise that already exist in the aviation community,
- to facilitate the transition of satellite navigation from R & D status to full operational status within the NAS, and
- to build the foundation for a seamless global satellite navigation system.

APPROACH

Initially, the program focus is on identifying and implementing the necessary augmentations to GPS to meet current civil aviation requirements. Flight tests, with user participation, will validate and quantify the operational benefits. The program will facilitate standards to enable timely production and certification of navigation receivers to serve as primary navigation aids during oceanic, en route, approach, missed approach, and departure phases of flight.

The overall program includes the establishment of a National Satellite Test Bed (NSTB) at the FAA Technical Center (FAATC) in Atlantic City, N.J. The test bed is being used to verify theoretical analyses, collect data in a realistic environment, interact with simulation systems to create extreme situations, test international interfaces, and provide a means of reducing and analyzing performance data. The NSTB will also help mitigate the technical and schedule risk associated with acceleration of the WAAS implementation.

As shown in Figure 1, the Satellite Navigation Program focuses on four major areas: technical activities, including research and development, the acquisition of a Wide Area Augmentation System (WAAS) and a Local Area Augmentation System (LAAS), operational support, and institutional activities.

The technical research and development activities focus on the DoD's GPS Standard Positioning Service (SPS) as well as any augmentations necessary to satisfy requirements for operations in the NAS.

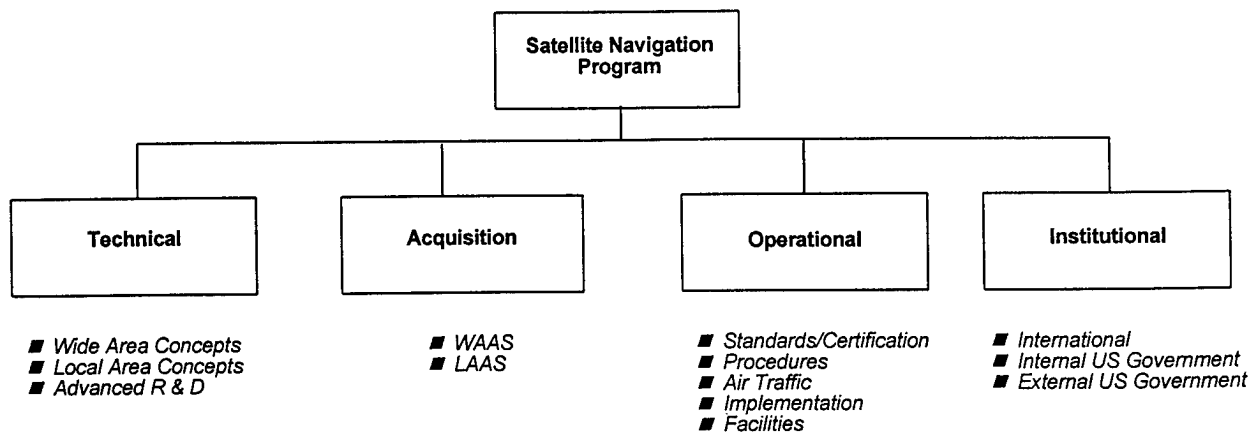
The WAAS and LAAS acquisition efforts evolved from the success of the respective research and development projects and are structured to produce augmentation systems able to satisfy civil aviation satellite navigation requirements at the earliest feasible date.

Operational support activities include the development and implementation of operational procedures, avionics certification standards, and supporting Air Traffic Control (ATC) functions. These activities also include flight trials to demonstrate the operational performance of the capabilities being implemented, development of simulators for training, and investigation/resolution of technical issues. In addition, a number of activities will be undertaken to ensure the development of facilities to support the operational implementation of the satellite navigation programs.

Institutional activities focus on the introduction of satellite-based navigation systems and concepts for early operational benefits and include involvement with foreign countries, international organizations, DoD, and civil aviation interests.

The four major program areas are further subdivided into a series of individual projects. More detail on each of these projects is contained in Appendix C. An overview of the technical research and development, acquisition, operational support, and institutional efforts follows.

Figure 1. Satellite Navigation Program Focus



Technical Research and Development

Background

Initial analyses have identified a number of concerns about the current GPS architecture in terms of its ability to satisfy civil aviation requirements. These concerns include:

- integrity,
- accuracy, and
- availability/continuity of service.

Integrity is the ability of a system to provide timely warnings to users when the system should not be used for navigation. The current GPS architecture cannot meet the 10-second warning criteria for nonprecision approach, the 6-second (or less) warning critical for precision approach, or the proposed 30-second threshold for en route operations.

Accuracy is the relationship between measured and true position. The GPS SPS without augmentation is only accurate enough to support phases of flight down to nonprecision approach minimums.

Availability describes when and where signals are adequate to permit users to determine their position to a specified accuracy and to continue to provide that specified accuracy (continuity of service). Viewed as an operational implementation issue, availability and continuity of service will largely determine the acceptance of satellite-based navigation.

Basic Augmentation Concepts

A number of basic augmentation concepts have been identified to address GPS integrity, accuracy, and availability/continuity of service concerns. The FAA Satellite Navigation Program will investigate the most promising of the alternatives to identify the most cost-effective approach to augmenting the GPS SPS.

Integrity

Satisfying integrity requirements for the various phases of flight is a critical prerequisite to the operational acceptance of GPS. Consequently, several technical options will be explored simultaneously. The intent is to assess the technical merits and operational practicality of each option, and, to the greatest possible extent, integrate the best features of each option into an optimal integrity solution. Technical options include:

- ground integrity determination,
- airborne autonomous integrity determination,
- combined ground and airborne integrity determination, and
- FAA-DoD integrity cooperation.

GROUND DETERMINATION OF GPS INTEGRITY

Under this option, GPS satellite transmissions are monitored at a precisely surveyed ground site. The ground site will be capable of detecting satellite anomalies and transmitting information to aviation users to alert the user of GPS satellite malfunctions that would affect the safe use of GPS for navigation. Objectives of this effort are to evaluate various alternatives for communicating integrity information to aviation users (for example, use of a pseudolite or a communication satellite) and to optimize the location of monitoring sites. Initial focus will be to optimize the monitoring network for the Continental United States (CONUS) operations while investigating the interest of other countries to be linked to the U.S. system.

AIRBORNE AUTONOMOUS INTEGRITY DETERMINATION

The GPS concept is based upon the use of four satellites with favorable geometry to compute a three-dimensional position suitable for navigation. The availability of positioning information from more than four sources, with good geometry, would make it possible to detect the presence of a malfunctioning satellite. Two options are currently being investigated to support internal GPS integrity determination: (1) receiver integrity determination using only satellites, and (2) receiver integrity determination using means other than satellites.

In the former concept, investigations are being conducted using the GPS constellation alone. The possible combination of GPS and another satellite system (such as the Russian GLONASS, or a geostationary satellite system) into a single receiver to provide an integrity determination is also being investigated.

The focus of the second option is to investigate alternative methods of providing one or more of the unknowns for a three-dimensional position solution. Candidate alternative means include inertial reference systems, barometric and radar altimetry, improved receiver clocks, and other radionavigation signals.

COMBINED GROUND AND AIRBORNE INTEGRITY DETERMINATION

This effort involves identification of the technical merits and operational practicality of both ground and airborne integrity determination techniques and the combination of the best features of each technique into an integrated, optimal integrity solution.

FAA-DOD INTEGRITY COOPERATION

The objective of this activity is to combine FAA and DoD resources in investigating both civil and military integrity requirements and to cooperate in the development and implementation of a mutually beneficial integrity solution.

Accuracy

The objective of the accuracy activities is to conduct the necessary research and development which will lead to the improvement of GPS accuracy for civil aviation. Specific focus will be placed on accuracy improvements to:

- enhance current operational procedures for oceanic, en route, terminal area, and nonprecision flight operations with the objective of improving safety, capacity, efficiency, and effectiveness; and
- enable CAT I, II, and III precision approaches, missed approaches, and departures (including curved, segmented, and parallel runway operations).

The following accuracy improvement activities are being conducted:

- Differential Code Corrections,
- Kinematic Carrier Phase Tracking, and
- Accuracy Augmentation.

DIFFERENTIAL CODE CORRECTIONS

The DGPS concept involves reception of satellite signals at a known, surveyed location, computation of a position based upon satellite transmissions, and comparison of the satellite-derived position with the surveyed location. The reference station at the surveyed location determines corrections to GPS transmissions to remove various error sources and transmits the corrections to users. Users apply the corrections to remove the errors. Under this portion of the effort, locations and operations of reference stations will be examined, and optimum means of communicating corrections to the users will be evaluated. Again, the focus of the reference station location effort will be to optimize the network for CONUS operations while investigating the interest of other countries to be linked to the U.S. system. Communications links to be evaluated include communication satellites, local area transmitters, and other communications links.

KINEMATIC CARRIER PHASE TRACKING

This project is closely related to the differential investigations outlined above. This effort, which is being conducted in cooperation with the National Aeronautics and Space Administration (NASA), universities, and industry, will assess the feasibility of a different receiver technique -- carrier phase tracking (the typical GPS receiver acquires and decodes satellite-transmitted navigation data messages to determine positions) and the extent to which carrier phase techniques provide enhanced, real-time position and velocity measurements. The project also includes a study of means of aiding the rapid determination of position using kinematic techniques. Pseudolites may be one option for that function.

ACCURACY AUGMENTATION

This option is directed at exploring augmentation techniques to (1) minimize the effects of the geometric magnification of satellite range errors, and (2) investigate alternative position information sources to improve overall position solutions. Specific investigations will address the use of:

- alternate GPS signal sources, such as satellites or ground-based transmitters (pseudolites), to broadcast GPS-like position and time information,
- other existing satellite signal sources such as GLONASS, and
- other sources of information to enhance or reduce accuracy errors (e.g., inertial reference platforms, highly accurate and/or multiple timing sources).

Availability

The SPS signals from the current 24-satellite constellation provide sufficient availability to support operations in oceanic en route airspace without further ground-based augmentation. However, in domestic en route airspace and during approach and landing, where aircraft fly in

closer proximity to each other and to the ground, the availability of the basic SPS signals must be further improved. Options being investigated for improving the availability of the basic SPS signals are similar to those outlined in the accuracy augmentation discussion above.

Acquisition

The successful completion of research and development activities will provide the basis for the acquisition of augmentations that will overcome the limitations of the GPS and permit safe and efficient use of the system in the NAS. The Satellite Navigation Program currently includes two acquisition activities: the WAAS and the LAAS. The WAAS is currently an ongoing effort; the LAAS is in the planning phase.

Wide Area Augmentation System

The WAAS is designed to provide the integrity, availability, and accuracy needed to support aviation requirements to use GPS as a primary means of navigation during all phases of flight through Category I precision approach. The WAAS has both a ground component and a space component. The ground component will consist of a number of Wide Area Reference Stations (WRSSs) and Wide Area Master Stations (WMSs) linked together by the FAA's terrestrial communications system. The space component will consist of a number of communications satellites linked to the ground component via Ground Earth Stations (GESs).

Background

In January of 1994, the Secretary of Transportation announced his intention to accelerate Global Positioning System (GPS) technology development and deployment and directed the modal Administrators to investigate methods for achieving earlier benefits for transportation.

Prior to the Secretary's announcement, the FAA had been actively pursuing a WAAS intended to augment the basic GPS services provided by the DoD and support flight operations in the NAS from en route through Category I precision approach.

On May 16, 1994, the Department of Transportation System Acquisition Review Council (TSARC) approved an accelerated schedule for the WAAS. The Satellite Program Office intends to proceed with this acquisition in accordance with existing Departmental and Agency regulations; however, the plan incorporates a tailoring and streamlining of these regulations to provide the earliest feasible operational capability for aviation users.

The WAAS development contract was awarded on August 3, 1995, with an operational implementation date two years ahead of original plans.

Approach

To be consistent with the DOT/DoD agreement concerning the civil use of GPS, the WAAS will be implemented in two phases. Phase one will provide operational benefits for en route through nonprecision approach operations; phase two will add the requisite levels of accuracy and redundancy to satisfy Category I precision approach requirements. WAAS acquisition will be accelerated by tailoring the acquisition process and use of concurrent engineering, thereby shortening the overall development process by taking steps in parallel instead of in series.

To focus staff resources in critical areas, the WAAS acquisition group has been divided into four teams: software, fielding, system engineering, and resource management. The software team will ensure certifiable software is developed to drive the WAAS. This software will operate all

components of the WAAS except the communication satellites. The fielding team will organize and manage the installation of WAAS components, including site preparation and system maintenance. The system engineering team is responsible for the development of the terrestrial and satellite communication services as well as such traditional system engineering functions as integration, human factors, configuration management, and safety. The resource management team will establish schedules, coordinate acquisition documentation, maintain necessary contract vehicles, and develop and maintain a robust program management information system.

Local Area Augmentation System

The second acquisition activity, currently in the planning stages, will entail procurement of a Local Area Augmentation System (LAAS). The LAAS will be capable of improving the integrity, availability, and accuracy of the basic GPS SPS to provide CAT I, II, and III capabilities at designated airports. Similar to the WAAS concept which incorporates the use of communication satellites for message broadcasts, a local area system will broadcast an augmenting message for a local geographic area via a line-of-sight communications link. The range of this service will extend to the limits of terminal airspace.

Operational Support

Background

To help ensure a timely transition to satellite-based navigation and landing services, a number of operational support activities will be conducted concurrently with the research and development, institutional, and acquisition activities. The operational support activities are focused on ensuring that the evolving systems meet operational requirements prior to their use and integration in the NAS.

The initial thrust of this effort was to focus on developing the requisite material to support GPS operations in the NAS using existing procedures and criteria by essentially overlaying GPS routes and approaches over the existing system. The FAA is already developing new GPS stand-alone procedures and criteria to fully exploit the capabilities of the increased position, velocity, and time accuracies inherent in satellite-based systems and employing these new procedures and criteria throughout the NAS.

Approach

The activities of the Operational support effort fall into the following five general categories:

- Standards and Certification,
- Procedures,
- Air Traffic,
- Implementation, and
- Facilities.

Close coordination among these five categories will be required throughout the operational implementation of GPS and GPS augmentation systems.

Standards and Certification Support

Avionics manufacturers are currently designing and producing GPS receivers for use in civil aircraft. Aircraft operators are anxious to equip their aircraft with GPS equipment. Such equipment and aircraft will require FAA certification before they may be operated in the NAS. This effort is designed to assist certification personnel in developing the requisite GPS avionics and equipment performance standards and to provide technical expertise to enhance their understanding of the issues associated with the various aspects of the GPS technology.

Procedures Support

Activities will be directed at developing new procedures and criteria to exploit the full potential of increased position, velocity, and time accuracies inherent in satellite-based navigation systems and, finally, employing these new procedures and criteria at specific locations. These activities include specifications and criteria for the development of GPS instrument operations for both fixed wing aircraft and helicopters. Examples of such activities include flight inspection hardware and software for both fixed wing and helicopter operations, the development of national databases for approach procedure tracking as well as airport survey information and receiver Navcard generation.

Air Traffic Support

To take full advantage of satellite technology for enhancing air traffic services in the oceanic, en route, domestic, and terminal environments, civil aviation will require the full support and approval of the appropriate air traffic control authorities. In effect, air traffic control will implement GPS and its augmentations at the day-to-day operating level. Ultimately, air traffic control (ATC) services will be a key factor in realizing the utility, effectiveness, and efficiency of satellite navigation technology and the benefits to be achieved by the aviation user community. Therefore, the focus of this effort will be to develop air traffic operating procedures and methods of practice in a timely manner for all types of aircraft, and provide the controller work force with the necessary education and training to enable optimum handling of satellite navigation equipped aircraft. Additional activities will concentrate on supporting actual procedural development in conjunction with ongoing automation system developments.

Implementation Support

To implement an orderly transition from ground-based to satellite-based navigation services within NAS, a number of activities will be undertaken to ensure that the criteria for operational implementation of the evolving systems are met prior to their integration into NAS. These activities include monitoring performance of the basic GPS signals to determine whether or not the specified level of services is being maintained. Flight trials will be conducted to demonstrate that the operational performance of the satellite navigation projects meets the FAA's criteria for their full implementation. FAA will be working with DoD and private industry to resolve a number of technical issues associated with the implementation of satellite-based navigation and landing services. Simulators and other training materials/standards will also be developed to support the training programs needed for a smooth transition to the satellite-based navigation and landing services.

Facilities Support

Closely related to Implementation Support, the objectives of this effort are to provide those facilities necessary to enhance interoperability of GPS and GPS augmentation systems. Satellite-based timing and positioning systems will be critical to the development and implementation of

future navigation and surveillance systems. The development of a Satellite Navigation Center (SNC) will provide critically needed services such as system management, performance monitoring, and information dissemination.

Process

A team concept will be used for building consensus and facilitating acceptance throughout operational implementation. These teams or forums between the FAA and user communities are based on three fundamental concepts:

- (1) identifying the proper customers,
- (2) actively supporting and encouraging customer participation in the process, and
- (3) understanding the requirements of those customers.

Satellite Navigation Program customers include internal FAA offices and other government agencies. External customers include avionics and aircraft manufacturers, airlines, business and general aviation and the industry groups which represent them. The current application activities reflect the immediate needs as expressed by internal and external customers. In developing the priorities for initiating and completing the activities throughout the operational requirements support effort, the Satellite Program Office supports and participates in the following teams:

- Satellite Operational Implementation Team (SOIT),
- Satellite Procedures Implementation Team (SPIT),
- Air Traffic Satellite Operational Implementation Team (ATSOIT), and
- Airway Facilities Satellite Operational Implementation Team (AFSOIT).

Satellite Operational Implementation Team (SOIT)

To achieve the safe and effective implementation of satellite navigation technology into the NAS, the FAA established a SOIT. The team consists of FAA experts in avionics certification, operational approval, instrument flight procedures, and other related operational disciplines. The SOIT has published a Technical Standard Order (TSO) for the use of GPS as a supplemental means of navigation. GPS nonprecision approaches have been produced as overlays to present nonprecision approach procedures. The SOIT will continue to be intimately involved in all activities leading to the timely introduction of satellite navigation into the NAS.

Satellite Procedures Implementation Team (SPIT)

The SPIT was formed as a subset of the SOIT in order to develop standards and guidance by which GPS instrument procedures will be implemented in the NAS. This team is composed of procedure experts from FAA Headquarters, each FAA region, and representatives from the National Ocean Service Office. Activities completed to date include the publication of an Advisory Circular (AC) defining data base requirements for GPS avionics, a comprehensive prioritization plan for processing and publishing the initial expected rush of GPS procedure requests and the establishment of a single, high integrity data base at the FAA Office of Aviation

System Standards to act as the national repository for all GPS survey and procedural data. Future work will be directed towards the development of new GPS procedural design criteria exploiting the latest GPS technologies and transition of a ground-based NAS infrastructure to a satellite-based system.

Air Traffic Satellite Operational Implementation Team (ATSOIT)

The ATSOIT is being established to guide, direct, and be responsible for the safe and orderly implementation of satellite technologies into the air traffic control environment. The ATSOIT is expected to accomplish the following:

- develop and establish policy for the Air Traffic Service,
- promote a total system approach to the implementation of satellite navigation for air traffic control using management principals that recognize the aviation industry as the customer,
- provide a single point of authority and approval for trials, tests, or demonstrations of satellite technology (equipment) by organizations inside or outside Air Traffic that may be used to provide benefits to users, and
- provide for full consideration of technical issues to provide solutions or a process to formulate solutions.

Airway Facilities Satellite Operational Implementation Team (AFSOIT)

The AFSOIT is being established to provide leadership in coordinating the operational implementation of existing and emerging technology into the air traffic control system. The AFSOIT is expected to accomplish the following:

- promote a total systems approach to the implementation of satellite technologies into the air traffic control system by, among other things, coordinating closely with the SOIT and other appropriate FAA organizations and elements,
- initiate development of policy and procedures necessary for timely use of satellite services by the aviation community,
- provide for full consideration of technical issues and provide solutions or a process to arrive at solutions, and
- maximize the benefits to the aviation community while keeping implementation costs at reasonable and affordable levels.

Institutional Activities

Background

In addition to the technical, operational support, and acquisition activities required to realize the full potential of satellite navigation, additional institutional efforts are required to resolve issues and build a consensus for accelerated implementation of GPS-based navigation services.

Approach

To achieve the needed consensus, institutional activities are being conducted concurrently in the following arenas:

- International,
- Internal U.S. Government, and
- External U.S. Government.

International

The objective of the international project is to enhance existing relations with other civil aviation authorities and appropriate organizations to create a seamless, worldwide satellite-based navigation system. A seamless worldwide satellite-based navigation system will permit the use of a single piece of avionics equipment to support aviation navigation on a global basis. Furthermore, it will provide the foundation for the next generation of communication, navigation, and surveillance systems. This overall objective is being fostered through a series of interrelated strategies.

The initial strategy of the international project is to provide educational and technical information to those interested parties involved in planning and conducting satellite navigation projects.

A second strategy of the international effort is to exchange information and perform cooperative research and development, including technology demonstrations, that will further the acceptance of GPS/GNSS internationally. These activities also enhance the objectives of the U.S. program, offering operational benefits to users at the earliest possible date.

Finally, the international project will assist in the development of compatible systems to achieve a seamless worldwide navigation system. Using bilateral agreements, these activities will foster the international acceptance of GPS/GNSS and ensure compatibility with initiatives such as the Wide Area Augmentation System by using similar augmentations developed by other countries.

A number of efforts are being undertaken to enable the United States to maintain a worldwide leadership role in promoting the adoption of satellite-based navigation systems for all phases of flight. Activities are being conducted in the following areas:

- Bilateral Cooperative Agreements,
- ICAO Panels, and
- GPS/GLONASS.

BILATERAL COOPERATIVE AGREEMENTS

The United States has signed bilateral cooperative agreements with 12 countries and Eurocontrol. These agreements address specific technological areas of mutual interest. These agreements cover the full spectrum of Program Office activities to include: the development of independent technical aspects of augmentation services, surface traffic management, combining of WAAS networks to form a seamless global system, and GPS/GLONASS. Additional bilateral agreements will be included in the future as additional needs and international interests evolve.

ICAO PANELS

At the 10th ICAO Air Navigation Conference held in Montreal in September 1991, the United States formally offered GPS as a candidate component of the GNSS. The final FANS Committee of the ICAO, proposed to the Air Navigation Council (ANC) the establishment of a GNSS panel to develop required characteristics of a future GNSS. The ANC approved the recommendation, and on October 17, 1994, the first Panel meeting convened in Montreal, Canada. One Panel accomplishment was to establish two working groups. Working Group A will address the development of materials that States and regions can use as guidelines for providing a means to realize early operational and economic benefits from existing satellite-based navigation systems. Working Group B will determine the system-generic standards and recommended practices (SARPS), guidance material, and system validation for GNSS necessary to allow any satellite-based navigation system to meet the established required navigation performance (RNP) or equivalent criteria. The United States reinforced its commitment to play an active role in all ICAO activities leading to cooperative development and establishment of an internationally accepted satellite-based navigation system.

The U.S. is also participating extensively in deliberations of the ICAO All Weather Operations Panel (AWOP). The panel endorsed the widely held conclusion that the many ongoing research and development activities throughout the world have demonstrated the technical feasibility of satellite technology for nonprecision and Category I precision approaches. The panel has agreed, with the full concurrence of the U.S., to conduct additional research and development into the following: (1) assessment of new technologies, including GNSS, for approach and landing operations, (2) further development of required navigation performance for approach and landing, and (3) assessment of the application of GNSS for surface movement guidance and control.

GPS/GLONASS

Neither the GPS nor the Russian GLONASS system alone is capable of meeting all of the requirements of civil aviation; however, it is conceivable that the integrated use of these two systems could result in a stand-alone civil aviation navigation system for all phases of flight down to nonprecision approach. Integrated use of GPS and GLONASS could afford sufficient redundant measurements to detect and isolate anomalies, thereby making receiver autonomous integrity monitoring continuously available. Integrated use of these systems holds major potential for providing enhanced benefits and safety in civil aviation.

Internal U.S. Government

DOT Pos/NAV EXECUTIVE COMMITTEE

In 1993, in a report to the Secretaries of Transportation and Defense, a joint DOT/DoD Task Force recommended that the Department of Transportation establish a Positioning and Navigation (Pos/Nav) Executive Committee. The DOT Pos/Nav Executive Committee would interact regularly with the already-established DoD Pos/Nav Executive Committee to discuss GPS policy and management issues. The FAA fully supported this recommendation. DOT has established a Pos/Nav Executive Committee as recommended by the Task Force. The FAA has been an active participant in all DOT Pos/Nav Executive Committee deliberations. The FAA will continue to support and actively participate in DOT Pos/Nav Executive Committee interactions with the DoD to establish and promote a national consensus on the management and operation of the GPS.

DoD

Since the DoD remains the operator of the basic GPS, it is essential that the FAA maintain close working relationships with the DoD to ensure that civil aviation needs are represented and well understood by the operator and that DoD interests are communicated to the aviation user. To foster these goals, the FAA has assigned a representative to serve as a DOT liaison officer to the Air Force Space Command at Peterson AFB, Colorado. The liaison officer will represent other modal elements of the DOT as well as aviation interests. The primary function of the position will be to interface on a daily basis with the DoD staff elements responsible for the day-to-day operation of the GPS and thereby contribute to ensuring that the needs of civil aviation are represented in GPS operational decisions.

Since the late 1970s, the DOT has assigned a Deputy Program Manager to the DoD GPS acquisition agency. To date, the DOT Deputy position has been filled by a Coast Guard officer. Negotiations are currently underway to transition the DOT Deputy position to the FAA. As the FAA fills this position, civil aviation interests will be represented on a day-to-day basis within the DoD's GPS acquisition agency.

Finally, the FAA and DoD are actively involved and cooperating in the definition of technical requirements and operational concepts for the SOC. Properly designed and implemented, the SOC has the potential to evolve into a robust backup GPS control facility as well as the operational center for the WAAS. FAA and DoD cooperative efforts on the SOC will help ensure the interoperability between the GPS and the WAAS.

RELATED GOVERNMENT PROGRAMS/PROJECTS

In addition to the primary activities of the satellite navigation program itself, the Satellite Program Office will provide support as necessary to other Government program and project managers. The introduction of GPS with its unprecedented worldwide position, velocity, and time accuracy may impact the development and operation of current or planned systems. In extreme cases, the potential capabilities of satellite navigation may render a current or developmental system obsolete. Consequently, the objectives of supporting related Government programs and projects are to:

- provide technical expertise to other program or project managers to help assess the benefits and/or impacts of satellite navigation systems in their areas of interest;
- where appropriate, recommend satellite navigation systems as an alternative or replacement method of determining position, time, or velocity information;
- where appropriate, promote the use of satellite navigation systems to provide position, time, or velocity information; and
- provide management with a focal point for determining how satellite navigation technology may be used to improve current systems and systems in development.

External U.S. Government

The purpose of this project is to coordinate and collaborate with civil users of the nation's aviation system to assure that their needs are considered in the design, acquisition, and implementation of satellite navigation. Users include the flying public, commercial and general aviation, service providers and operators, academia, as well as manufacturers of satellite navigation-related equipment. The specific objectives of this activity are to improve the

efficiency and safety of the National Airspace System, capitalize on new and emerging satellite technologies, and foster U.S. technology.

The goals and objectives of this activity are realized through the collaborative efforts and exchanges of information between the Program Office and users of the system. The Program Office will work with the user community to exchange information and to develop plans and carry out demonstrations and tests that contribute to the safe incorporation of satellite navigation capabilities into the operational environment as quickly as possible. Cooperative programs with user organizations to demonstrate and test nonprecision approaches at airfields throughout the nation will continue to be planned and executed. Arrangements with airlines for joint tests of new concepts and equipment in the operational environment will continue.

In 1992 and 1993 the Satellite Program Office established direct contact with 75 groups involved in some way with civil aviation. The Program Office outlined in broad terms the goals of the Satellite Navigation Program and elicited comments and suggestions from the groups. Feedback from these groups has been instrumental in shaping the direction of the Program.

The Program Office will continue to maintain close liaison with manufacturers, service providers, and operators and will participate in and contribute to councils, seminars, conferences, and symposiums to stay informed of activities and advances in satellite navigation technology. The Program Office will provide information to help U.S. industry compete successfully in global markets and expand employment opportunities for the U.S. work force. Maximum use will be made of informational vehicles such as multimedia, videos, brochures, and exhibits to convey the program plans and activities to the user community as well as to provide the needed training to agency personnel so the benefits of satellite navigation can be realized as quickly and safely as possible.

In an effort to keep all interested and affected parties apprised of developments in the Satellite Navigation Program, the Satellite Program Office publishes a quarterly newsletter, *Satnav News*. This newsletter currently has a circulation of several thousand readers and provides them with updates of the latest happenings in satellite navigation.

PROGRAM MILESTONES

Implementation dates are provided in Appendix D.

Appendix A

Global Positioning System

The Navstar GPS is a satellite-based radionavigation, positioning, and time transfer system operated by the DoD. GPS consists of three major segments: space, control, and user.

The GPS space segment contains 24 operational satellites. The satellites are deployed in six orbital planes, each containing a total of four satellites. The satellite orbital planes have an inclination relative to the equator of 55 degrees, and the orbit height is 20,200 km (10,900 nm). Each satellite completes an orbit in approximately 12 hours (11 hours and 56 minutes).

The satellites radiate spread spectrum signals at two frequencies, L1 and L2 (1,575 MHz and 1,227 MHz, respectively). The use of two frequencies provides for the correction of most of the L-band signal propagation delay. The operational satellites are three axis stabilized, employ solar panels for power, have batteries to carry them through eclipse periods, and weigh approximately 1,850 pounds (840 kg).

The satellites are positioned in orbit so that a minimum of four are always observable by a user anywhere on earth. The satellites are not uniformly spaced in each orbital plane. The spacing between some adjacent satellites is greater than the corresponding distance between others. The purpose of this arrangement is to minimize the impact on coverage due to the loss of as many as three satellites. An observer on the ground will see the same satellite ground track each day; however, each satellite will become visible four minutes earlier each day due to a four-minute-per-day difference between the satellite orbit time and the rotation of the earth.

The GPS control segment consists of a Master Control Station, five monitor stations, and three ground antennas. The Master Control Station is located at Falcon Air Force Base in Colorado Springs, Colorado. The monitor stations are located at the Master Control Station, Hawaii, Kwajalein, Diego Garcia, and Ascension Island. The latter three monitor stations also have ground antennas for two-way communications with the GPS satellites.

The remote monitor stations are unattended data collection centers under the direct control of the Master Control Station. Each monitor station contains six 2-channel GPS receivers, environmental data sensors, an atomic frequency standard, and a computer processor. The monitor stations use the GPS receivers to passively track all GPS satellites in view and measure pseudorange and delta pseudorange (integrated Doppler) of the satellite spread spectrum signal with respect to the local atomic standard. The monitor stations also detect the navigation data on the spread spectrum signal. The environmental sensors collect local meteorological data for later

tropospheric signal delay corrections at the Master Control Station. The computer processor controls all data collection at the monitor station and provides the communications interface with the Master Control Station. All data collected at the monitor station is buffered at the monitor station and then relayed upon request to the Master Control Station for processing.

The GPS Master Control Station provides the interface between the control segment and the satellites. It uses an S-band command and control uplink to unload data into a satellite navigation processor. Data uploaded by the Master Control Station can be user navigation data, which the satellite broadcasts in its navigation message, requests for processor diagnostics, or commands to change the satellite time provided to the user in the navigation data message.

The Master Control Station completely controls the operation of the control segment. It performs the computations needed to determine extremely precise satellite orbits and satellite atomic clock errors. It generates updates of satellite uploads of user navigation data and maintains a record of each satellite's navigation processor contents and status.

The updated information is transmitted to each satellite via the ground antennas. The ground antennas also transmit and receive satellite control and monitoring signals.

The user segment consists of the GPS receivers and the associated equipment. The GPS receivers, using data transmitted by the satellites, derive position, navigation, and time information and display the appropriate data to individual GPS users.

GPS operation is based upon the concept of satellite ranging. Essentially, users figure their position on earth by measuring their distance from a group of satellites in space. The satellites act as precise reference points. Position determinations are based on the measurement of the transit time of radio frequency (RF) signals from a number of GPS satellites. All GPS position determinations are based upon an Earth Centered, Earth Fixed coordinate system, WGS-84.

GPS provides two levels of service: a Standard Positioning Service (SPS) and a Precise Positioning Service (PPS).

SPS is the standard level of positioning and timing accuracy available to any user on a continuous, worldwide basis. The accuracy of this service is adjustable by the system operator, the U.S. DoD, and will be based upon U.S. national security interests. Current U.S. policy specifies a daily, worldwide horizontal positioning accuracy of 100 meters (95%) and 300 meters with a probability of 99.99 percent and a vertical accuracy of 156 meters (95%) GPS SPS availability is specified to be in excess of 99%. Timing/time interval accuracy is within 340 nanoseconds of Coordinated Universal Time (UTC).

PPS is the most accurate positioning, velocity, and timing information continuously available, worldwide from the GPS. This level of service is limited to authorized U.S. and allied military, federal government, and civil users who can satisfy specific U.S. requirements. The PPS provides a predictable positioning accuracy of at least 17.8 meters (95%) horizontally and 27.7 meters (2 sigma) vertically. Velocity accuracy is 0.1 meters per second (rms) or better.

1 2 sigma ~ 96%

Appendix B

GLONASS

The Russian Federation is in the process of developing and implementing GLONASS to provide signals from space for accurate determination of position, velocity, and time by suitably equipped users. GLONASS will provide high accuracy and availability to users. Navigation coverage will be continuous, worldwide, and all-weather. Three-dimensional position and velocity determinations are based upon the measurement of transit time and Doppler shift of RF signals transmitted by GLONASS satellites.

When fully operational, the GLONASS space segment will consist of 24 satellites (21 operational and 3 spares). GLONASS satellites orbit at an altitude of 19,100 kilometers with an orbital period of 11 hours and 15 minutes. Eight evenly spaced satellites are to be arranged in each of three orbital planes, inclined at 64.8 degrees and spaced 120 degrees apart.

The GLONASS ground segment performs satellite monitoring and control functions and determines the navigation data to be modulated on the coded satellite navigation signals. The ground segment includes tracking and monitoring stations and a Master Control Station.

Measurement data from each monitoring station is processed at the Master Control Station and used to compute the navigation data that is uploaded to the satellites via the upload station. Operation of the system requires precise synchronization of satellite clocks with GLONASS system time. To accomplish the necessary synchronization, clock correction parameters are provided by the Master Control Station.

A navigation message transmitted from each satellite consists of satellite coordinates, velocity vector components, corrections to GLONASS system time, and satellite health information. To obtain a system fix, a user's receiver tracks at least four satellite signals, either simultaneously or sequentially, and solves four simultaneous equations for the three components of position and time. (A position solution may be derived from three satellites if an external source of time or altitude is provided.)

GLONASS satellites broadcast in two L-band portions of the RF spectrum (L1 - 1602.5 Mhz to 1615.5 Mhz and L2 - 1246.4 Mhz to 1256.5 Mhz) and have two binary codes, the C/A code and the P code, and the data message. GLONASS is based upon a frequency division multiple access (FDMA) concept. GLONASS satellites transmit carrier signals in different L-band channels, i.e., at different frequencies. A GLONASS receiver separates the total incoming signal from all

visible satellites by assigning different frequencies to its tracking channels. The use of FDMA permits each GLONASS satellite to transmit identical P and C/A codes.

In GLONASS, the C/A code is modulated onto the L1 carrier only; the P code is transmitted on both L1 and L2. Receivers designed to operate with only the C/A code can use only the L1 signal for ranging; P code-capable receivers can use both frequencies to measure range. The use of both frequencies provides a means of correcting for ionospheric refraction. Only the C/A code is available for civil use.

The frequency of the GLONASS P code, 5.11 MHz, is ten times higher than the frequency of the C/A code, 0.511 MHz. Since the higher code frequencies generally provide a better range measuring accuracy than lower frequencies, GLONASS has a precise mode of operation with the P code and a less accurate mode using the C/A code. GLONASS performance specifications for accuracy (95%) are: 100 meters in horizontal position, 150 meters in vertical position, 15 centimeters per second in velocity, and 1 microsecond in time.

Each GLONASS satellite transmits navigation data at a rate of 50 bits per second. The navigation data message provides information regarding the status of the individual transmitting satellite along with information on the remainder of the satellite constellation. From a user's perspective, the primary elements of information in a GLONASS satellite transmission are the clock correction parameters and the satellite position (ephemeris). GLONASS clock corrections provide data detailing the difference between the individual satellite's time and GLONASS system time, which is related to UTC (SU).

GLONASS satellites broadcast their three-dimensional position, velocity, and acceleration for every half-hour epoch in an earth-centered, earth-fixed (ECEF) coordinate frame referred to as PE-90. For a measurement time somewhere between the half-hour epochs, a user interpolates the satellite's coordinates using position, velocity, and acceleration from the half-hour marks before and after the measurement time.

As of May 1, 1995, 19 GLONASS satellites were active and designated as being healthy. All 19 satellites are model IIe, with a design life of three years. According to a recently activated GLONASS Information Center, the constellation is planned to reach its full strength of 24 satellites by the end of 1995.

Appendix C

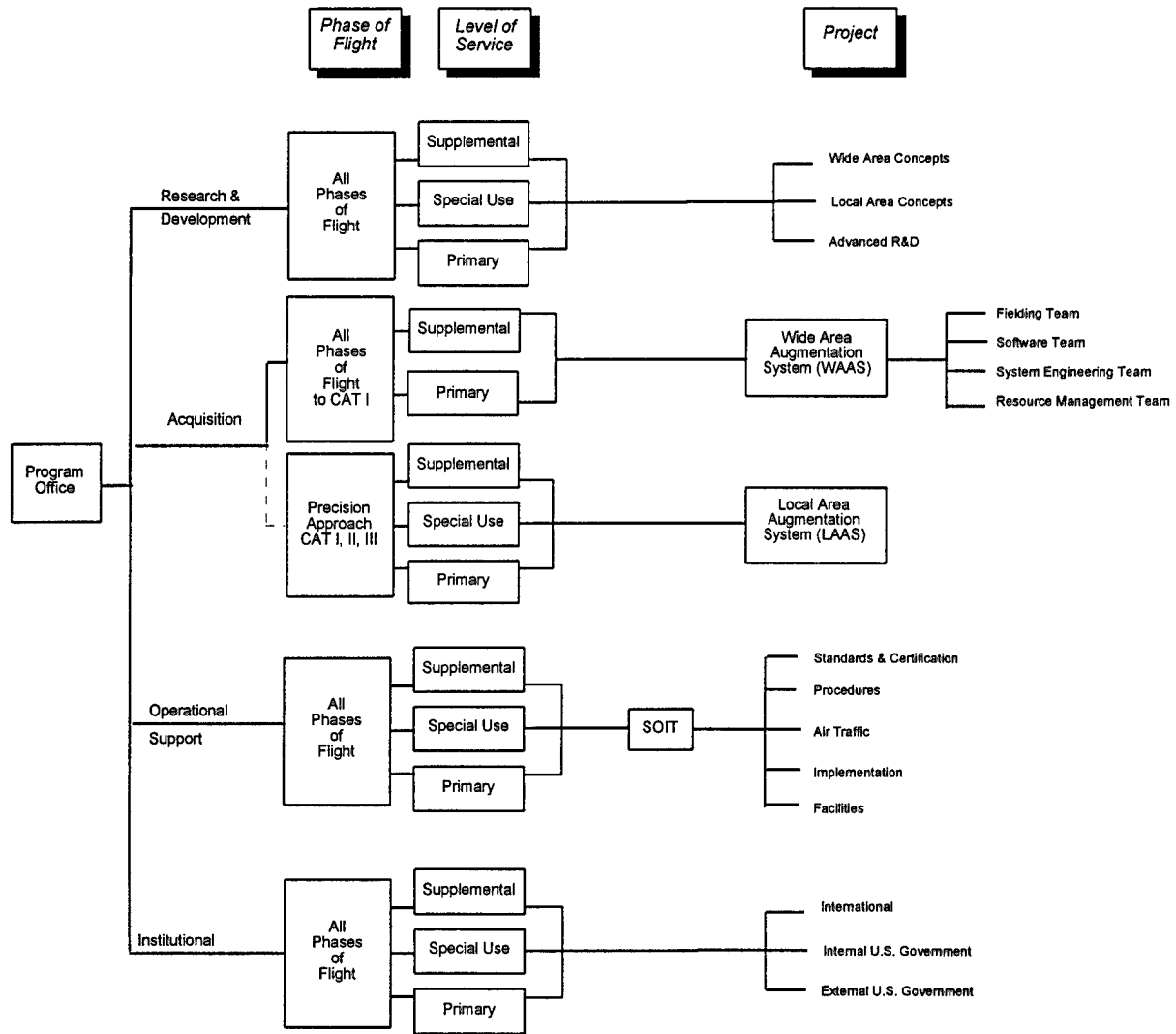
Project Descriptions

Introduction

This appendix contains a description of each of the projects which comprise the Satellite Navigation Program.

Figure C-1 illustrates the Program Office structure and lists the team activities associated with the WAAS acquisition. In addition to the WAAS acquisition, planning is underway to pursue a Local Area Augmentation System (LAAS) should such a system be desired and/or necessary to satisfy precision approach operations beyond those provided by the WAAS.

Figure C-1. Satellite Navigation Program Structure



Wide Area Concepts

Program Area: *Technical*

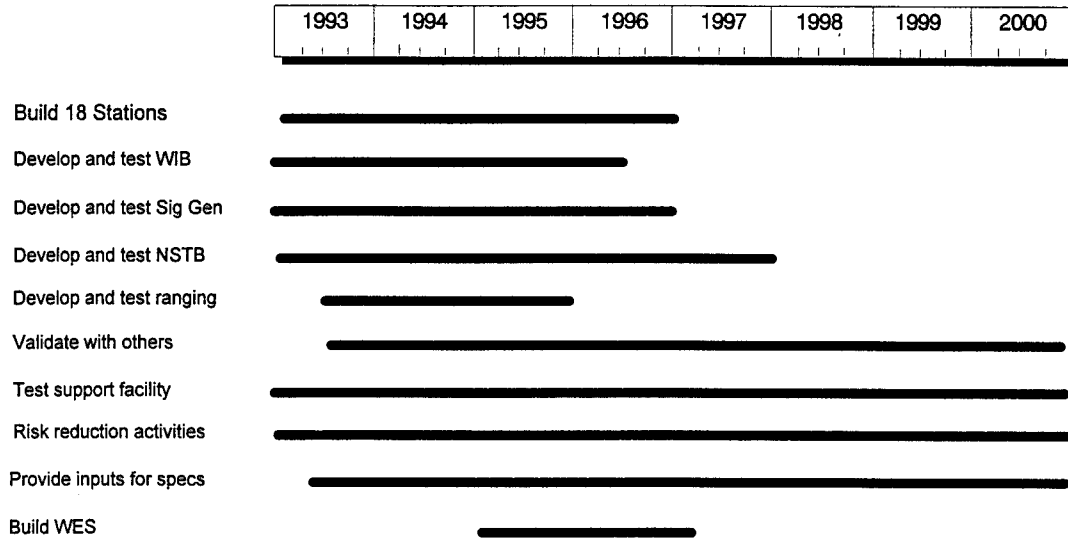
Objectives:

- To develop and test feasibility of using a Wide Area Integrity Broadcast (WIB) to improve availability of GPS navigation to satisfy the Required Navigation Performance (RNP) for domestic en route, terminal, and nonprecision approaches.
- To develop and test feasibility of using a Wide Area Differential GPS (WDGPS) broadcast to improve integrity and accuracies of GPS navigation to satisfy both Supplemental and RNP requirements for precision approaches down to CAT I weather minimums.
- To develop and test feasibility of using the WIB/WDGPS broadcast as another source for pseudo ranges to improve the availability of GPS navigation to help satisfy the RNP requirements for domestic en route, terminal, precision and nonprecision approaches.
- To provide enhanced inputs for the development of functional specifications for phased acquisition of WIB, WDGPS, and Ranging.
- Test and evaluate international interfaces planned to support seamless, global WAAS implementation.

Technical Approach:

- Build, test, and verify 18 interconnected GPS Wide Area Reference Stations (WRSs).
- Build, test, and verify four Wide Area Master Stations (WMSs).
- Develop, test, and verify WIB algorithms at the WRSs.
- Build, test, and verify two Ground Earth Stations (GES) for WIB/DGPS at COMSAT earth stations and use the capabilities of existing Inmarsat II geostationary satellites.
- Develop, test, and verify WDGPS algorithms at the ground reference stations.
- Develop, test, and verify WDGPS algorithm at the ground monitoring stations.
- Develop, test, and verify Ranging algorithms at the ground earth station so that the WIB/WDGPS can be used as a source for another pseudo range.
- Validate wide area concepts by interfacing with additional ground stations supplied by other organizations (both Government and Industry, including any International agencies).
- Develop and maintain a WAAS environmental simulator (WES).
- Develop and maintain a test support facility at the FAATC to perform ground and airborne tests to verify wide area concepts.
- Reduce risk by analyzing and testing backup modes for redundancy and fail-safe requirements.
- Develop, test, verify, and quantify options to be exercised in the WAAS Acquisition.
- Develop, test, and verify improvements to ionospheric modeling activities to support DGPS accuracy enhancements.

Schedule:

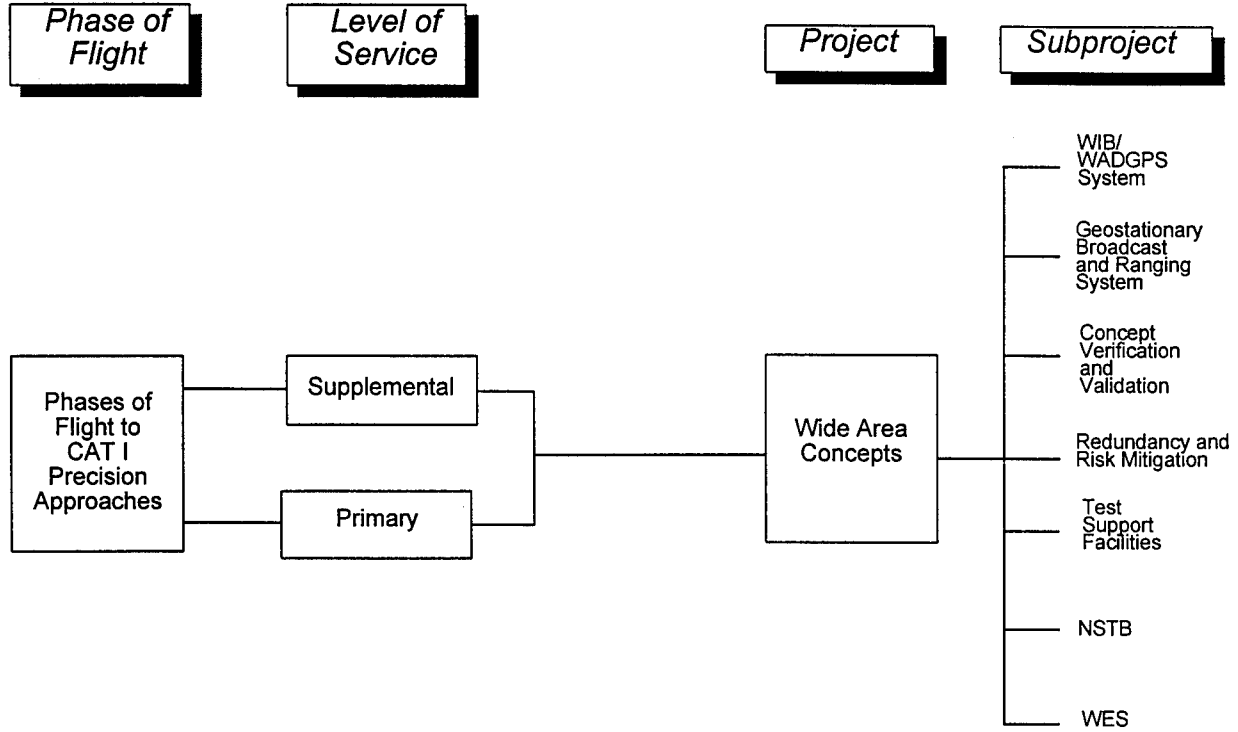


Satellite Program Office Point of Contact:

J.C. Johns

Project Structure:

Figure C-2. Wide Area Concepts Project Structure



Local Area Concepts

Program Area: *Technical*

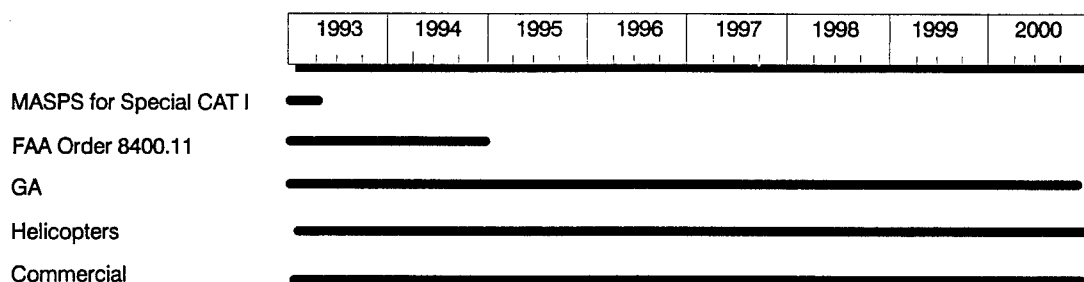
Objectives:

- Investigate augmentations to GPS in order to support CAT I precision approaches for all aircraft types. Operationally approve a Special CAT I procedure for commercial and general aviation aircraft.
- Complete investigation of techniques required to support Category I/II/III operations with a Federally procured LADGPS.

Approach:

- Research and develop methods for utilizing GPS with a local differential system to satisfy present CAT I precision approach requirements.
- Create Minimum Aviation System Performance Standards (MASPS) for special use CAT I approach in RTCA SC159, WG4.
- Create FAA Order 8400.11 to operationally approve a Special CAT I.
- Test LADGPS for general aviation aircraft use and operationally approve a Special CAT I procedure.
- Test LADGPS for helicopter use and operationally approve a Special CAT I procedure at a heliport.
- Test LADGPS for commercial aviation aircraft with ATA and various manufacturers and operationally approve a Special CAT I procedure; also examine feasibility of different datalinks to carry differential and integrity information.
- Foster the process of approving LADGPS systems for part 171, and AIP funding.
- Develop framework for transitioning LADGPS into a Local Area Augmentation System (LAAS) acquisition.
- Investigate advanced integrity concepts to support LAAS operations.
- Investigate pseudolites as an aid to LAAS continuity/availability.
- Choose the optimum system configuration for the LAAS.
- Investigate advanced LADGPS techniques for future development and LAAS risk mitigation.

Schedule:

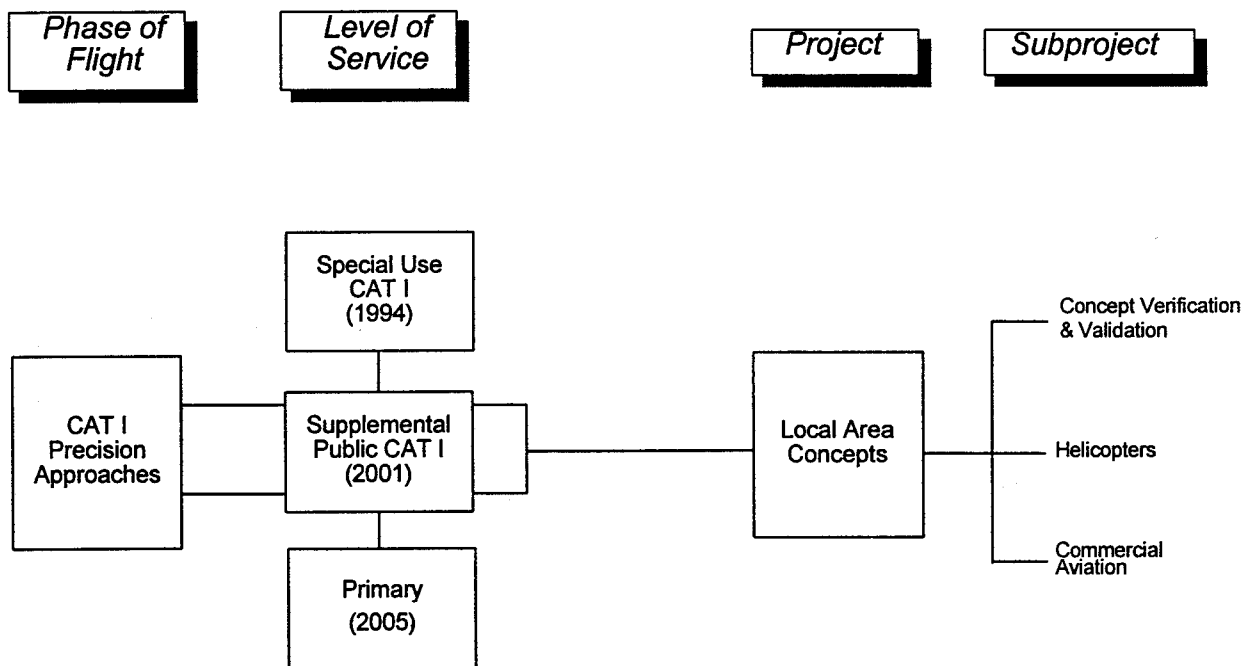


Satellite Program Office Point of Contact:

Ray Swider

Project Structure:

Figure C-3. Local Area Concepts Project Structure



Advanced Research And Development

Program Area: *Technical*

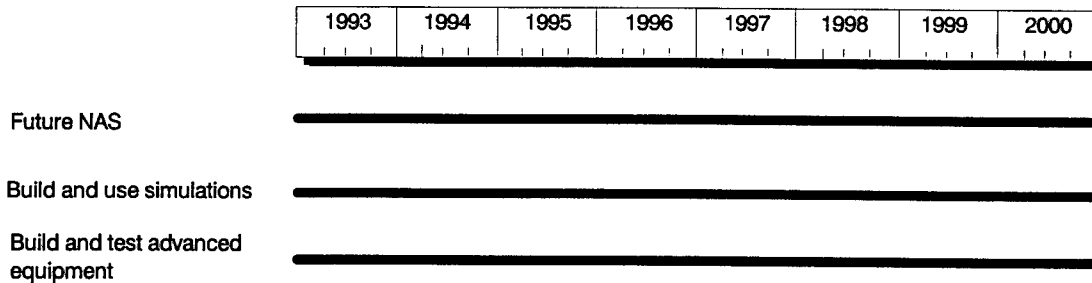
Objective:

- To investigate the feasibility of using satellite-based positioning systems for advanced applications within the NAS.

Technical Approach:

- Perform significant advanced research and development activities through the University centers of excellence.
- Develop, analyze, and simulate different future concepts for use of satellite-based communications, navigation, and surveillance (CNS) within the NAS.
- Build and test advanced avionics, both hardware and software for future CNS applications.
- Build and test advanced ground differential systems (e.g., pseudolites).

Schedule:



Key Personnel:

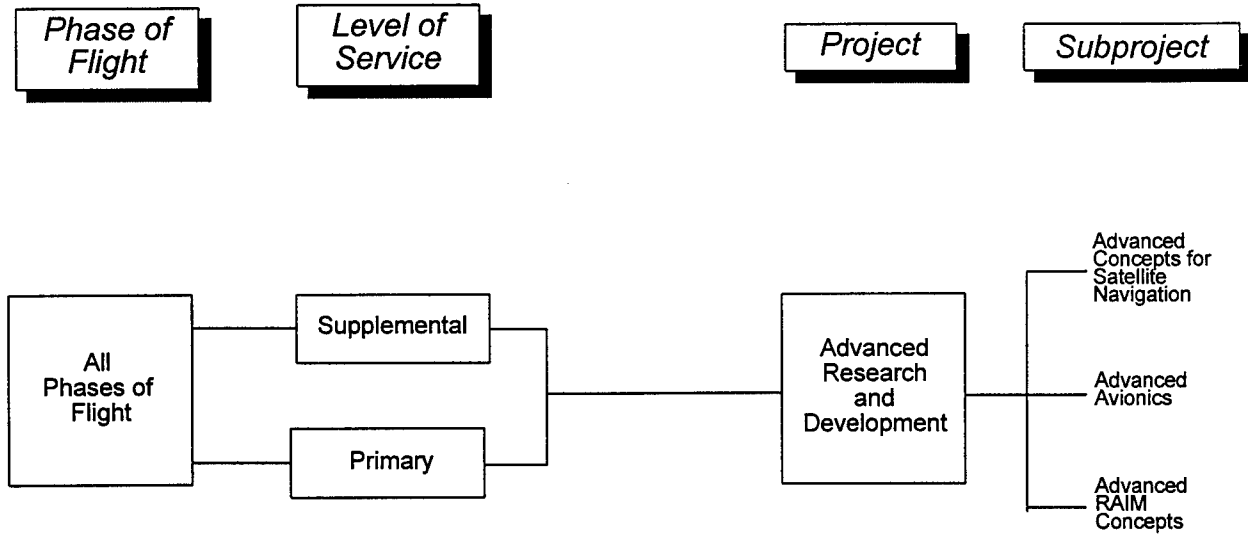
Brad Parkinson - Stanford
Bill Michaelson - WPI
Steve Copps - Intermetrics

Satellite Program Office Point of Contact:

Joe Dorfler

Project Structure:

Figure C- 4. Advanced R&D Project Structure



WAAS Acquisition

Program Area: *Acquisition*

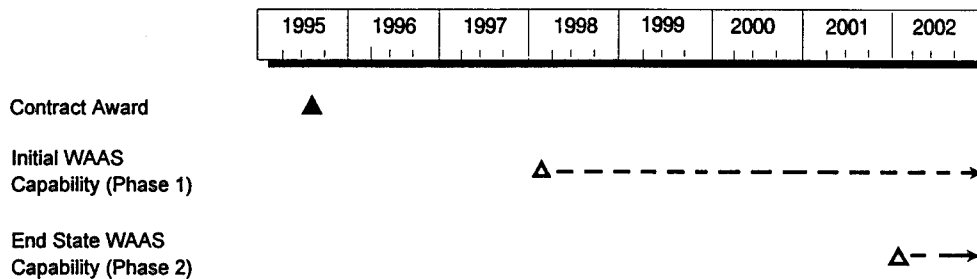
Objective:

- To acquire and field, on an accelerated basis, a system to augment the GPS SPS by providing integrity, availability, and increased accuracy for all phases of flight through precision approach.

Technical Approach:

- Conduct a streamlined, major system acquisition in accordance with OMB Circular A-109 and FAA Order 1810.1F.
- Successfully implement a single contract for the design, development fielding, installation, and support of a WAAS to provide an initial operational capability by early 1998.

Schedule:

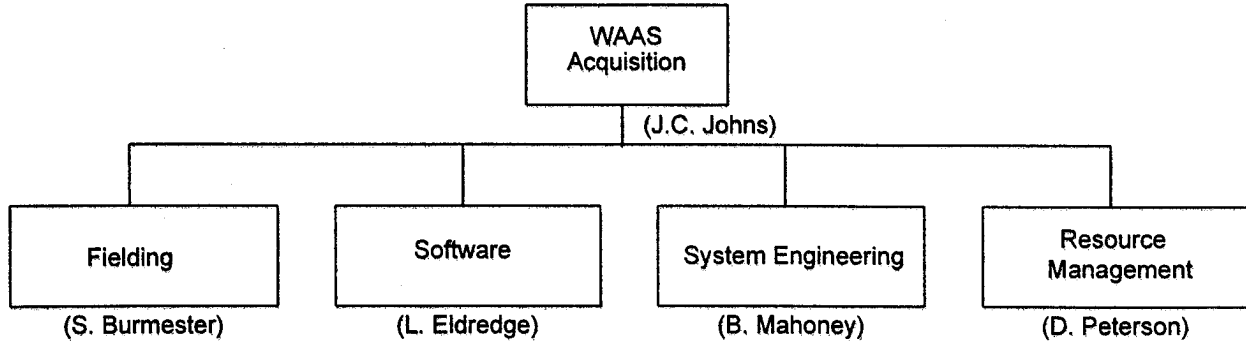


Satellite Program Office Point Of Contact:

J.C. Johns

Project Structure:

Figure C-5. Wide Area Augmentation System Project Structure



LAAS Acquisition

Program Area: *Acquisition*

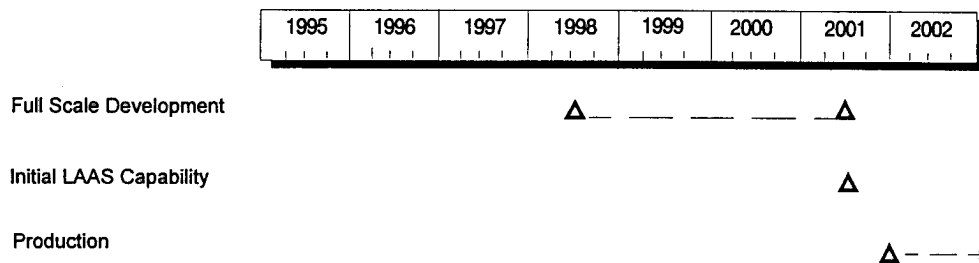
Objectives:

- To acquire and field systems to augment the GPS SPS and complement the WAAS to support precision approaches and landings of all types (CAT I/II/III).

Technical Approach:

- Conduct a tailored major system acquisition in accordance with OMB Circular A-109 and FAA Order 1810.1F.
- Award, on a competitive basis, contracts for the design, development fielding, installation, and support of a LAAS to provide an initial capability by the year 2001.
- Select a single contractor to produce, install, and provide interim logistics support for a minimum of 152 local area augmentation systems.

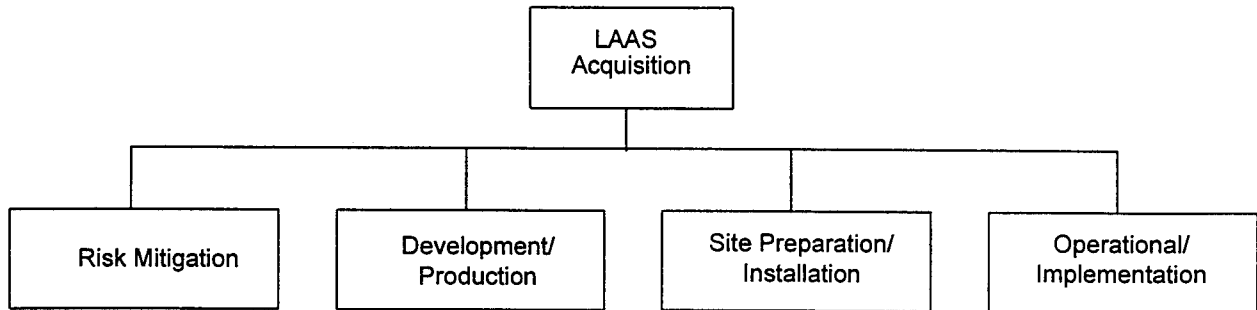
Schedule:



Satellite Program Office Point Of Contact:
Ray Swider

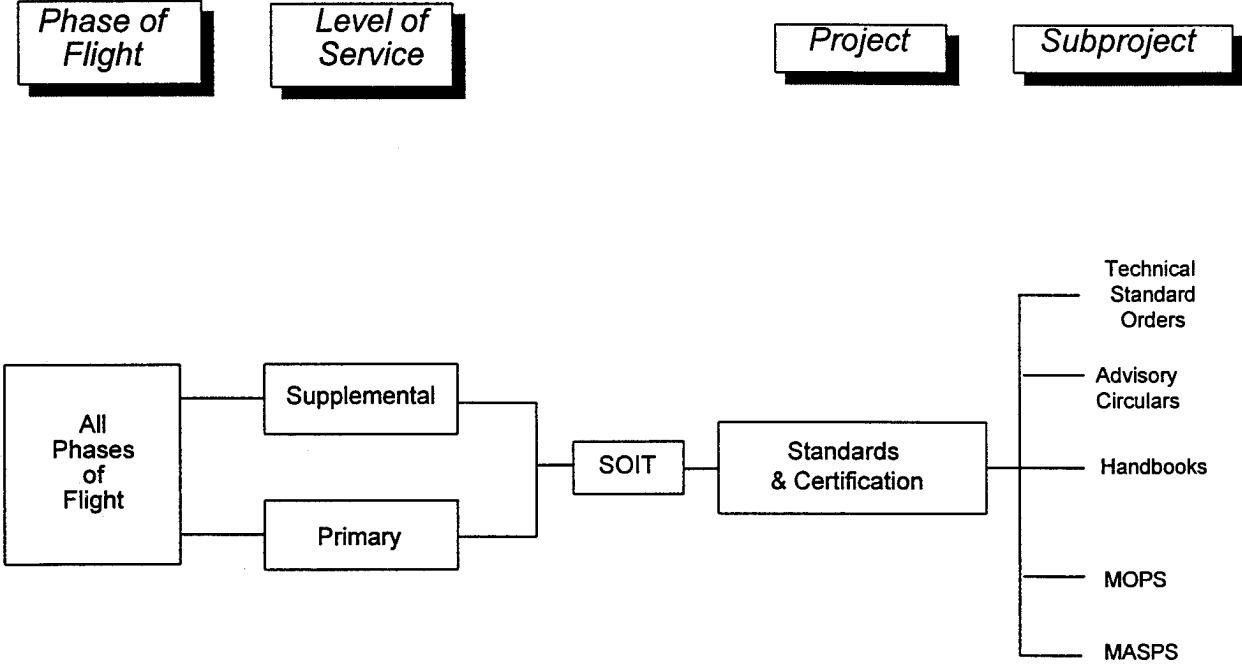
Project Structure:

Figure C- 6. Local Area Augmentation System Project Structure



Project Structure:

Figure C-7. Standards & Certification Project Structure



Procedures

Program Area: *Operational*

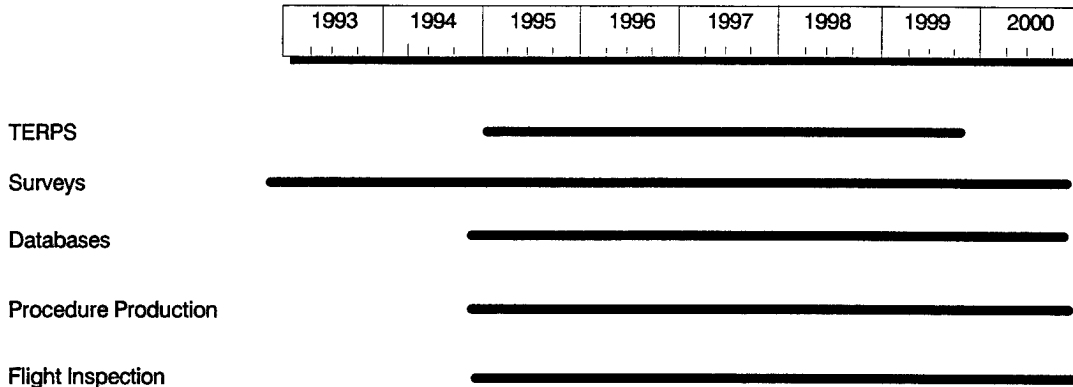
Objective:

- To develop flight operations procedures, and other aviation standards (e.g., flight inspection, airport surveys, database development) to support GPS operations in the National Airspace System (NAS).

Technical Approach:

- Develop procedure design criteria and production capability to support stand-alone GPS approaches in addition to the overlaying of existing instrument approaches.
- Develop a simulator capability to support procedure development.
- Determine the nature and extent of GPS Flight Inspection procedures.
- Perform and validate GPS geodetic surveys for all airports.

Schedule:

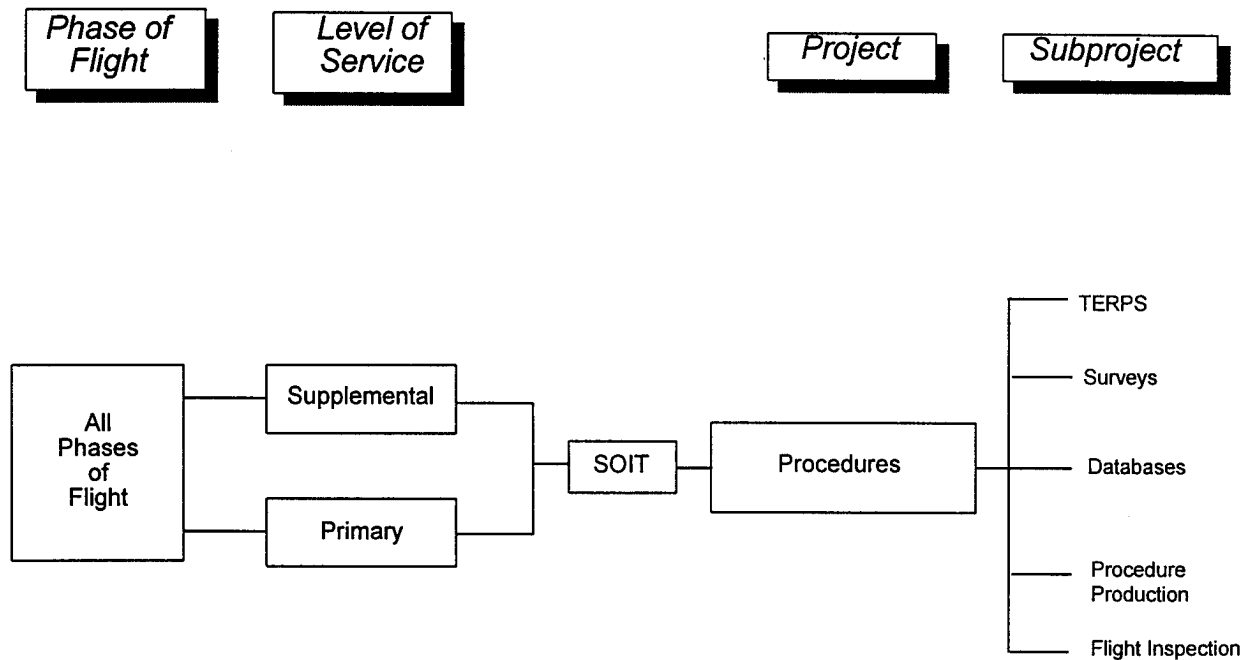


Satellite Program Office Point of Contact:

Mike Shaw

Project Structure:

Figure C- 8. Procedures Project Structure



Air Traffic

Program Area: *Operational*

Objective:

- To develop air traffic standard operating procedures and methods of practice for supporting satellite-based navigation route/approach development for all types of aircraft operations. Air Traffic procedures and methods include activities such as regional airspace management, NOTAMS and aeronautical information pertaining to satellite navigation, approach standards, en route modeling/simulation, air traffic transition planning, capacity enhancement, and controller training.

Technical Approach:

- Develop and implement a satellite navigation transition plan for controllers, Flight Service Station specialists, inspectors, designees, and other appropriate personnel to include human factors issues.

Schedule:

1993	1994	1995	1996	1997	1998	1999	2000
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NOTAMS/Aeronautical
Information



Airspace Actions



Modeling/Simulation



System Capacity Studies

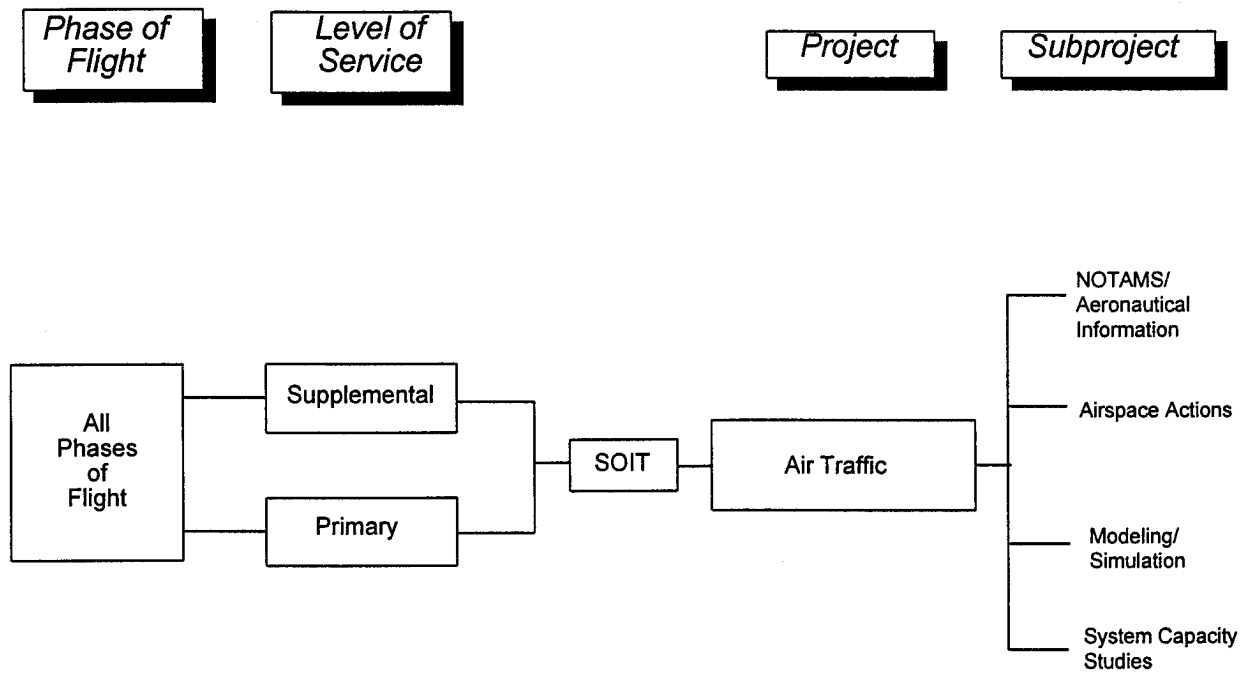


Satellite Program Office Point of Contact:

Mike Shaw

Project Structure:

Figure C-9. Air Traffic Project Structure



Implementation

Program Area: *Operational*

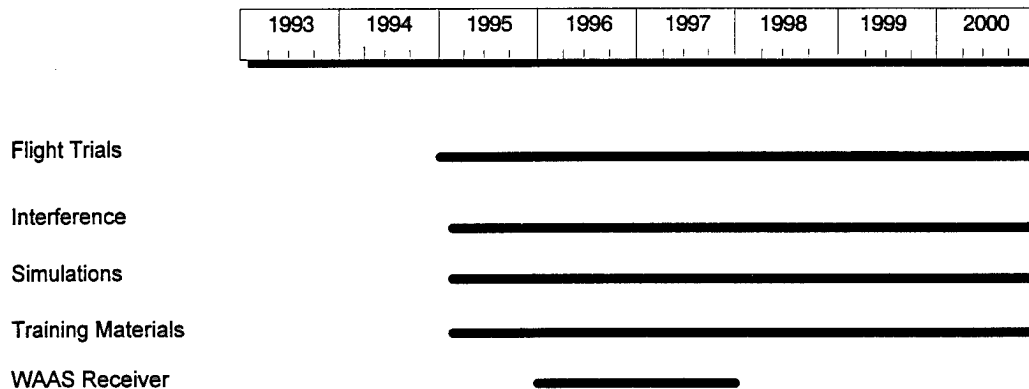
Objective:

- To implement an orderly transition from ground-based to satellite-based navigation within NAS. Includes development of training materials/standards, interference studies, performance monitoring, flight trials to demonstrate operational performance, and simulations to support procedure development and human factor studies.

Technical Approach:

- Conduct flight trials to demonstrate the operational performance of the evolving systems and monitor performance of the GPS signal.
- Develop the capability to investigate, analyze, and mitigate interference anomalies.
- Develop simulations to support procedure development and human factor studies.
- Develop training materials/standards to facilitate a smooth transition to satellite-based navigation and landing systems.
- Develop a receiver compliant with WAAS MOPS established by RTCA.

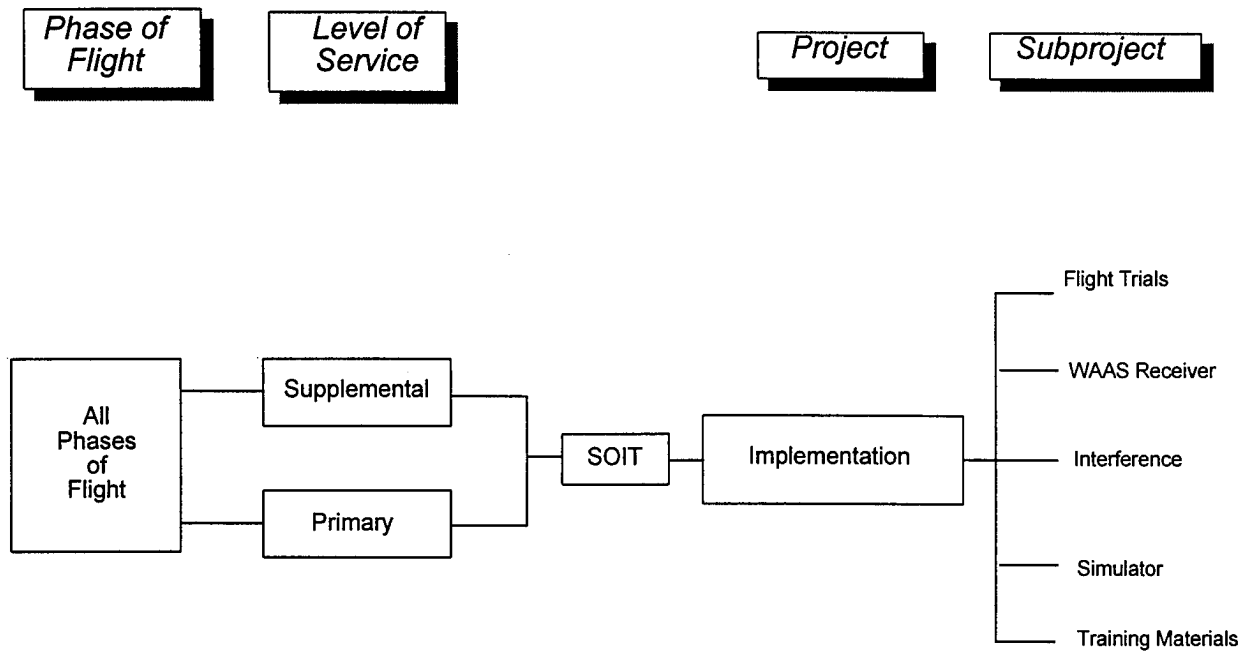
Schedule:



Satellite Program Office Point of Contact:

Mike Shaw

Figure C- 10. Implementation Project Structure



Facilities

Program Area: *Operational*

Objective:

- To provide those facilities necessary to enhance interoperability of GPS and GPS augmentation systems.

Technical Approach:

- Establish a Satellite Operations Center (SOC) to provide a centralized facility for all civil satellite navigation operations.
- To provide support for other Governmental satellite-based time/position/navigation programs to include ongoing DoD activities.

Schedule:

1993	1994	1995	1996	1997	1998	1999	2000

Satellite Operations Center



Air Traffic System Monitors

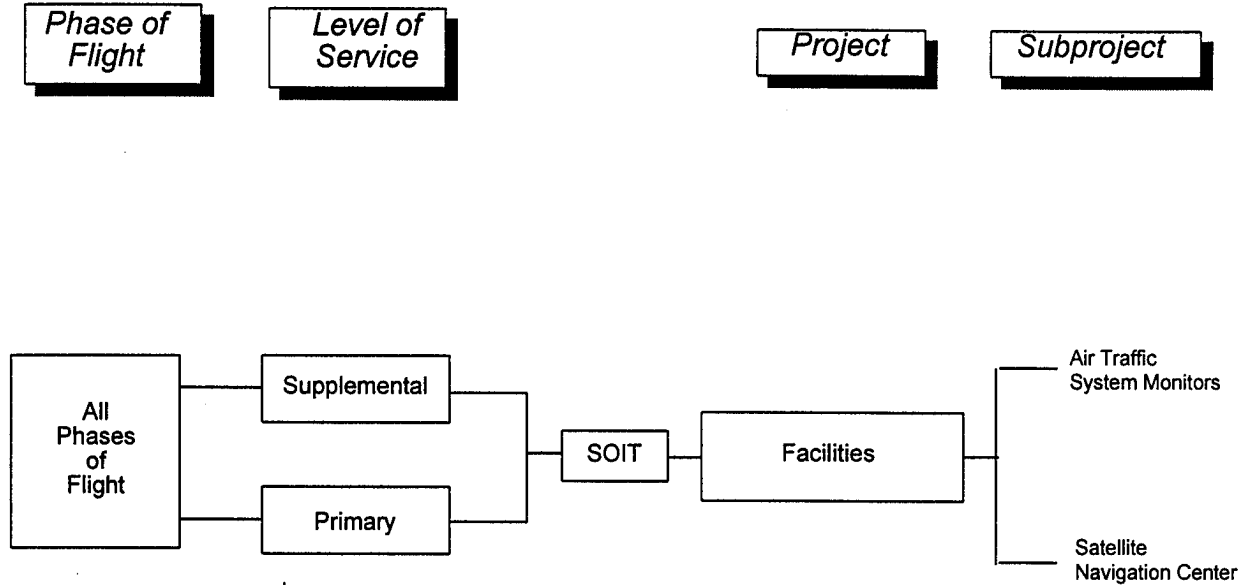


Satellite Program Office Point of Contact:

Mike Shaw

Project Structure:

Figure C- 11. Facilities Project Structure



International

Program Area: *Institutional*

Objectives:

- To foster the acceptance of satellite-based technology in a global market.
- To establish positive relations that will aid in the international acceptance of GPS as a component of a Global Navigation Satellite System (GNSS).
- To provide support to individual countries or regions where the operational benefits of a GNSS will enhance aviation.
- To support development of a seamless worldwide Wide Area Augmentation System (WAAS) for GPS/GNSS.
- To foster U.S. political and/or foreign policy goals.

Technical Approach:

- Provide educational, technical, and operational information for the various Satellite Navigation projects such as: Wide Area Concepts, Local Area Concepts, and Operational Concepts. These information exchanges and cooperative technological and operational projects will both further the acceptance of GPS/GNSS in the international arena and enhance the objectives of the U.S. program, offering real-world benefits to users at the earliest possible date.

Schedule:

1993	1994	1995	1996	1997	1998	1999	2000
------	------	------	------	------	------	------	------

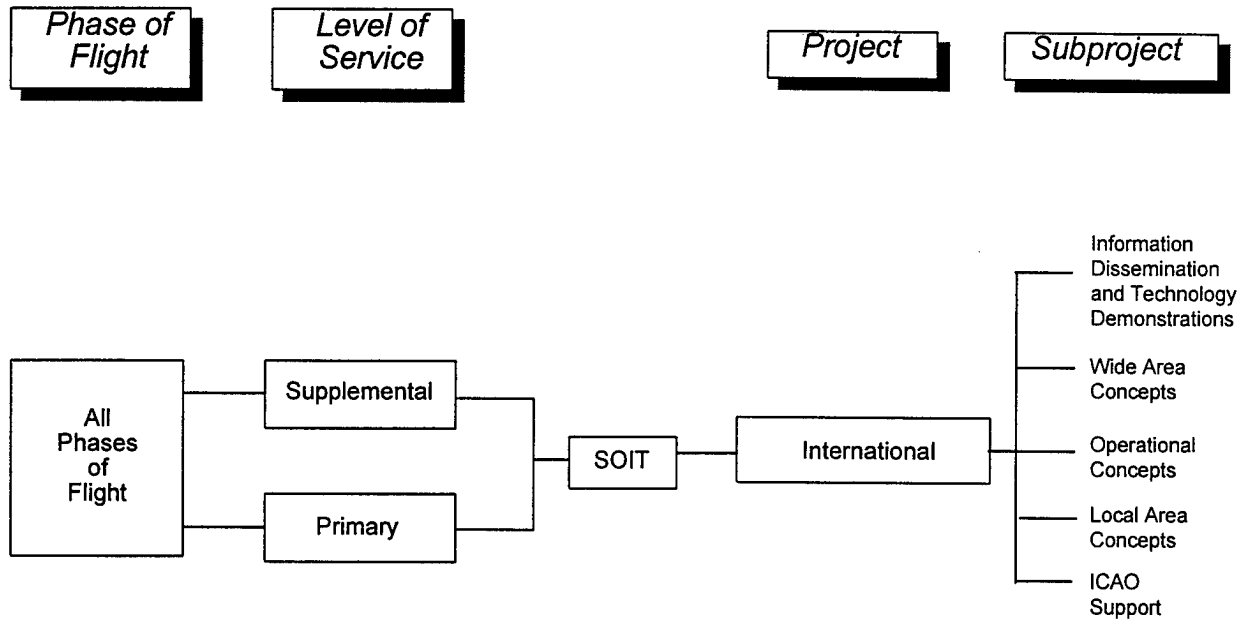
WAAS	_____
LAAS	_____
Information and Demos	_____
Ops Concepts (As Required)	

Satellite Program Office Point of Contact:

Joe Dorfler

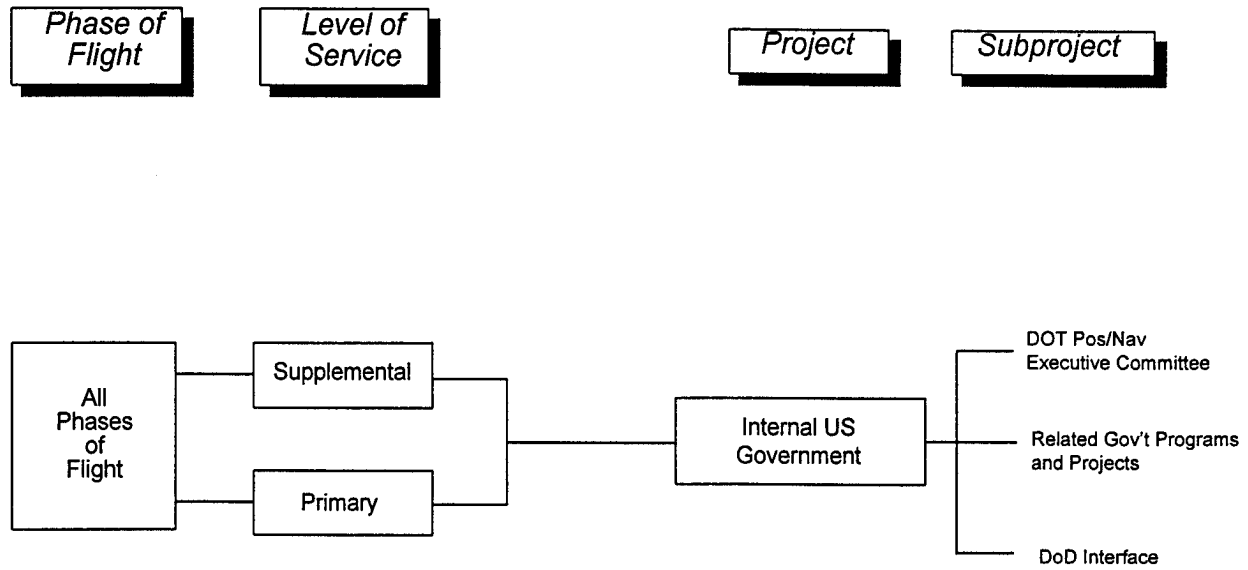
Project Structure:

Figure C- 12. International Project Structure



Project Structure:

Figure C-13. Internal US Government Project Structure



External U.S. Government

Program Area: *Institutional*

Objective

- To establish and participate in forums, foster cooperative efforts, and build a consensus for accelerated implementation of GPS-based navigation services between and among affected elements of the nongovernmental U.S. civil aviation community.

Technical Approach

- To support and participate actively in satellite navigation-related working groups established and conducted by civil aviation interests such as RTCA, Inc., ATA, NBAA, and AOPA.
- To cooperate and collaborate with civil aviation interests to demonstrate and test satellite navigation capabilities in an operational environment.
- To disseminate information to the civil user community using vehicles such as multimedia, videos, brochures, exhibits, and a quarterly newsletter.
- To carefully evaluate recommendations of civil aviation interests for more effective approaches to accelerating the implementation of GPS-based navigation services in the NAS.

Schedule

1993	1994	1995	1996	1997	1998	1999	2000
------	------	------	------	------	------	------	------

External Government
Groups

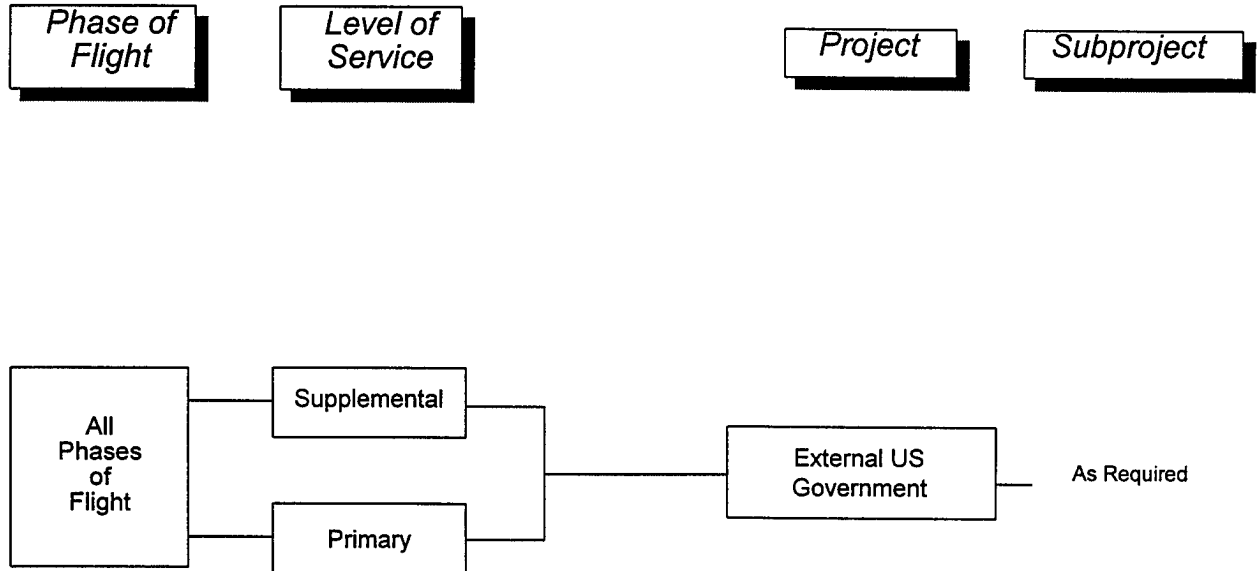


Satellite Program Office Point of Contact

Joe Dorfler

Project Structure:

Figure C-14. External US Government Project Structure



Appendix D

Implementation Schedules

Projected Civil Aviation GPS Operational Implementation

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
GPS as Input to Multi Sensor Nav														
En Route Oceanic	→	→	→											
En Route Domestic	→	→	→											
Terminal	→	→	→											
GPS as Supplemental Nav														
En Route Oceanic	→	→	→	→										
En Route Domestic	→	→	→	→										
Terminal	→	→	→	→										
Non-Precision Approach	→	→	→	→										
Precision Approach CAT I (Special)														
Precision Approach CAT I (Public)														
Precision Approach CAT I *														
GPS as Primary Nav														
En Route Oceanic (GPS w/FMS, IRS & ADC)														
En Route Domestic *														
Terminal *														
Non-Precision Approach *														
Precision Approach CAT I *														
Precision Approach CAT II & III														

* Based on Projected WAAS Schedule

Appendix E

Program Manager's Charter



U.S. Department
of Transportation
**Federal Aviation
Administration**

Memorandum

Subject: **ACTION:** Program Manager's Charter for
the Satellite Program

Date: NOV 24 1992

From: Program Manager, Satellite
Program Office, ARD-70

Reply to
Attn. of: JDorfler

To: The Administrator
THRU: The Deputy Administrator

Attached is a copy of my proposed Program Manager's Charter for the Satellite Program. This Charter is adapted from program managers' charters currently in effect for the acquisitions within the NAS Development Program (AND). The changes included reflect the research and development flavor of the program. As projects within the program mature to the full scale development and limited production phase, the management responsibility will transition to AND.

If you agree with the Program Manager's Charter as written, I will start to operate within the confines of that document immediately. Should any modification or revisions to the Charter be required by any new or revised major system acquisition management order, they will be made and submitted for your review and approval.


Joseph F. Dorfler

Attachment: _____

Concur:  _____

Nonconcur: _____

Date: 12-9-92

Charter for the Program Manager

1.0 Purpose

This charter defines the functions, responsibilities, authority, and accountability of the Program Manager (PM) for the Federal Aviation Administration (FAA) satellite program of the Research and Development Service. It also defines the relationships between the satellite program and other supporting FAA organizations, Government agencies, contractors, Congress, and the aviation user community.

2.0 References

- a. DOT Order 4200.15C, Major Systems Acquisition Review and Approval, April 20, 1990.
- b. FAA Order 1810.IE, Major Systems Acquisition.
- c. Acquisition Guide for Program Managers, February 1991.

3.0 Program Description

The Satellite Program Office (SPO) is currently providing the requisite research, development, planning, programming, and implementation guidance for the FAA's implementation of satellite technology in the areas of navigation and communication. The overall objective of the satellite program is to support the operational use of satellite navigation and communication technologies for all civil aviation needs: oceanic, en route, terminal, nonprecision, and precision approaches. The SPO is unique because operational use of satellites for navigation and communication can be implemented, for some aviation needs, without any FAA procurement. The satellite program, currently identified in the Satellite Navigation Plan and the Satellite Communications Plan (draft), contributes to this overall objective by developing and testing the feasibility-of various satellite techniques/technologies, while at the same time supporting the development of operational procedures and standards to satisfy civil aviation requirements for all phases of flight.

Satellite Navigation

Satellite navigation presents opportunities for standardized, worldwide civil aviation operations using a common navigation receiver and for significant improvements in safety, capacity, service flexibility, and operating costs. Adoption of satellite navigation systems could lead to the eventual phaseout of the existing National Airspace System (NAS) ground equipment while maintaining or improving existing levels of service. In addition, satellite-based navigation systems provide the potential for new navigation and landing services not currently provided by existing systems.

Satellite navigation potential and opportunities have prompted the aviation industry to begin producing satellite navigation receivers, and aviation users are demanding avionic standards and operational guidance for their use. However, satellite navigation systems, specifically the global positioning system (GPS), have not yet been declared operational. Technical concerns such as system integrity and accuracy must be thoroughly investigated prior to permitting operational use. Additionally, a sound transition plan with supporting minimum operational performance standards, certification criteria, and air traffic procedures must be developed to ensure a smooth transition from today's way of doing business to tomorrow's satellite-based navigation systems.

The aggressive, early exploitation of satellite navigation technology provides substantial benefits in meeting a number of FAA and aviation user goals:

- Consolidation of navigation functions to enable the eventual phaseout of older navigation equipment at substantial savings.
- Improved safety with reduced separation minimums resulting in increased system capacity.
- significant reductions in aircraft operating costs through the use of efficient user-preferred route structures.
- Accurate position reporting to enable uniformly, worldwide high-quality air traffic management (ATM).

- Improved ground and cockpit situational awareness to reduce runway incursion.
- Increased landing capacity with up to Category I precision approach services to all runways, helipads, and airports for all aircraft types.

Since GPS will be the cornerstone of global navigation satellite system (GNSS) and is under U.S. Government control, the initial focus of the FAA satellite program will be on GPS. As information is made readily available on additional satellite navigation systems such as global orbiting navigation satellite system, the scope of the satellite program will be broadened to include all such systems which may become GNSS components.

Satellite Communications

The satellite communications program contributes to the overall objective by supporting the development of national and international standards for mobile satellite communications; testing and analyzing the performance and availability of the satellite communications system; and flight testing initial and prototype hardware.

Mobile satellite communications present opportunities for standardized, worldwide civil aviation operations using a common communications system not limited to line-of-sight constraints of terrestrial-based communication systems (VHF and Mode-S) or unreliable high frequency (HF) propagation conditions. There is an immediate need for improved communications for oceanic operations; the implementation of mobile satellite communication is one element necessary for significant improvements in safety, capacity, service flexibility, and operating costs. In domestic airspace, adoption of mobile satellite communication systems can provide service in remote areas in the near term and, in the far term, could lead to an eventual phaseout of NAS ground equipment while maintaining or improving existing levels of service.

Mobile satellite communications potential and opportunities have prompted the aviation industry to begin producing mobile satellite communication receivers and have prompted mobile satellite service suppliers to begin making the service

available. Technical concerns such as availability and system performance will be thoroughly investigated during initial engineering trials and analysis. The initial satellite communications capability has been approved for aircraft company communications and for limited air traffic control communications.

The aggressive, early exploitation of mobile satellite communication technology provides substantial benefits in meeting a number of FAA and aviation user goals:

- Accurate and timely position reporting to enable uniformly, worldwide high-quality ATM.
- Improved cockpit capability due to use of data messages and improved clarity of satellite voice communications over HF voice communications.
- Significant reductions in aircraft operating costs through the use of efficient route structures.
- Improved safety with reduced separation minimums resulting in increased system capacity.

Since INMARSAT has provided the foundations of the aeronautical mobile satellite service (AMSS), the FAA's initial focus is on development of AMSS for operational use. INMARSAT has on-orbit satellites providing nearly global coverage, and the INMARSAT signatories have the ground equipment in place to provide AMSS capability. The initial equipment developed by avionics manufacturers will enable limited satellite communications service via service providers such as ARINC. The service will provide some operational benefits and will enable the airlines and FAA to develop operational experience with satellite communications.

4.0 Matrix Management

The PM will accomplish the majority of the functions by the use of matrix management techniques with established functional organizations. This will require the PM to integrate the efforts of a broad range of supporting organizations within FAA

headquarters, other Government agencies, and other organizations such as: MIT Lincoln Laboratory, Naval Observatory, and MITRE. The timely continuous support of these various organizations is essential for successful mission accomplishment.

As an integral part of the matrix management concept, acquisition streamlining, and total quality management, the PM will maximize the use of concurrent engineering with industry, leverage private company research and development dollars, and reduce the effective time from laboratory to field utilization. The PM will ensure that aviation industry is actively involved in the conceptual development, requirements definition, and field testing and will also be the FAA primary focal point on satellite utilization/technology for all interfaces and in coordination with external user organizations (e.g., ATA and AOPA).

The PM will negotiate official agreements with each supporting organization (memorandums of understanding, letters of agreement, and interagency agreements). These agreements will describe the tasks to be performed, products to be delivered, time schedules and milestones, and resource requirements (cost and personnel) and will commit the supporting organization to satisfactory completion of the agreed-upon cost, schedules, and technical performance. This concept will facilitate effective tracking of supporting organizations' activities and assist the PM in managing the program. The PM is responsible for the overall management of activities performed under these agreements, periodic review of accomplishments, tracking of program resources consumed, and final review and approval of all tasks and products.

5.0 Functions And Responsibilities

a. Major Functions and Duties

1. The PM has sole responsibility for the overall programmatic management, preparation of all program documentation, and direction of all FAA activities necessary for successful development, procurement, test and evaluation, and engineering support for the completion of the satellite program.

2. The PM presents and defends the satellite program to the Acquisition Review Committee, executes the program as approved at each key decision point, presents program status at major systems acquisition reviews, and formulates a program management organization to comply with FAA orders, policies, directives, and procedures.

3. The PM is responsible for defining all tasks to be performed, principal products, staffing estimates, contract cost estimates, budget estimates, schedules, management procedures and controls, and required equipment and facilities.

4. The PM serves as the principal liaison with supporting agencies and the primary point of contact with all external user groups on all matters concerning satellite navigation and communications technology.

5. The PM establishes matrix support agreements with other functional organizations, foreign governments, aviation user groups, the general public, and Congress. The PM shall coordinate public statements with the office of Public Affairs as provided for in order 1200.8C, Public Information Activities and Programs. No one, except for those exercising direct authority over the SPO, shall make public statements regarding the satellite program unless the statements are cleared and approved by the SPO.

6. The PM ensures timely preparation and submission of reports documenting changes in established cost, schedule, benefit, and budget baselines for use by higher officials.

7. The PM has the following responsibilities which are accomplished by working with and through the FAA's functional managers:

- Establishing a uniform interpretation of the program/contract requirements.
- Developing a comprehensive plan to meet the requirements.

- Staffing the satellite program with qualified people in needed disciplines.
- obtaining adequate funding to accomplish the program.
- Accomplishing both the technical and business objectives of the program.
- maintaining a continuous overview of the program's progress so that timely corrective action can be taken when necessary.
- Maintaining control of cost, schedule, and technical performance quality.

b. Budget and Resource Management

1. The PM evaluates the impact of proposals to increase or decrease the resources authorized for program execution. The PM will estimate the effect of proposed changes on schedules, procurement plans, and performance objectives and will document the results. officials having final decision authority during reprogramming and budgeting deliberations shall take the PM's evaluation into consideration when making decisions on program status and funding.

2. The PM will inform the Administrator, through channels, about the existence of any situation where program objectives cannot be met with available resources and within the established schedule.

3. The PM, operating within authorized resources, exercises fiscal responsibilities for budget formulation and execution, including preparation of financial plans, budget estimates, program change requests, and reprogramming within that authority allowed by legal and administrative regulations.

c. Program Master Plan

1. The PM is responsible for preparing a Satellite Program Master Plan and submitting it to the Associate Administrator for System Engineering and Development for approval. The PM is also responsible for updating the program

master plan as necessary. The master plan will describe the following: major tasks to be performed; planned task agreements (program directives) identifying both the activities and office, service, center, and regional directors being asked to perform those activities; products, schedules, and major milestones; and estimates of resources and budget requirements.

2. The PM is responsible for ensuring that satellite developmental activities adhere to the program master plan as approved by the Associate Administrator for System Engineering and Development. The PM must coordinate all substantive changes to the plan, including performance, funding, schedules, and requirements, with the Associate Administrator for System Engineering and Development.

6.0 Authority And Accountability

Effective October 20, 1992, Mr. Joseph F. Dorfler (ARD-70) is designated as the PM for the satellite program and was given authority to organize and execute the program in accordance with the authority and direction provided for in this charter.

The PM is the single central executive responsible to the FAA for managing the program and accomplishing the functions and duties stated in this charter. The PM has broad directive authority within the scope of the program to plan, direct, control, and use resources of not only the program office but also program related, in-house resources and contractor organizations, including the assignment of appropriate responsibilities to the various FAA functional organizations. As the responsible executive, the PM is expected to act on matters affecting the program. When action is required beyond the authority granted in the charter, the PM will refer the action to the appropriate authority, describing all available alternatives and a recommended course of action.

The PM's authority is limited as follows:

- a. The PM does not have the authority to deviate from policy established by higher authorities.
- b. The PM must ensure that communication, action, or inaction in any form that contractors may interpret as

direction shall be conducted through a duly authorized contracting officer.

- c. The PM receives authority from and is directly accountable to the Administrator for discharge of the latter's responsibility as the acquisition executive for the FAA. The PM manages and directs the ongoing performance of the satellite program throughout research, development, procurement, and implementation, as directed; makes program recommendations; and advises appropriate authorities of program status and progress.

Appendix F

Milestones

To date, a number of important milestones leading to the operational implementation of GPS have already been achieved. Some of the more important of these are listed below:

Milestone	Date
Mission Need Approved	October 1992
TSO C-129 Approved	December 1992
Supplemental Use of GPS For Enroute through Nonprecision Approach Authorized	June 1993
CAT III Precision Approach Feasibility RFP Issued	September 1993
First WAAS Instrument Approaches Tested	September 1993
WAAS Cross-Country Demo Conducted	December 1993
DoD Designates GPS Operational	December 1993
FAA Sanctions Use of GPS	February 1994
WAAS Development Authorized	April 1994
WAAS RFP Issued	June 1994
Cat II/III Feasibility Contracts Awarded	June 1994
First GPS Instrument Approach Procedures Published	July 1994
GPS Implementation Plan for Air Navigation and Landing Published	August 1994
FAA Order 8400.11, SCAT I, Published	September 1994
FAA Administrator reaffirms US Offer of GPS SPS	October 1994
ICAO Council Accepts US GPS SPS Offer	October 1994
GPS Authorized "Primary Means" for Oceanic, Remote Operations	December 1994
WAAS Development Contract Awarded	August 1995

Appendix G

Acronyms

A

AC	Advisory Circular
ADS	Automatic Dependent Surveillance
AF	Airway Facilities
AFSOIT	Airway Facilities Satellite Operational Implementation Team
AIP	Airport Improvement Program
AMSS	Aeronautical Mobile Satellite Service
ANC	Air Navigation Council (of ICAO)
AOPA	Aircraft Owners and Pilots Association
AT	Air Traffic
ATA	Airline Transit Association
ATC	Air Traffic Control
ATM	Air Traffic Management
ATSOIT	Air Traffic Satellite Operational Implementation Team
AWOP	All Weather Operations Panel (of ICAO)

C

C/A	Coarse Acquisition
CAT	Category
CONUS	Continental U.S.; Conterminous/Contiguous U.S.
CNS	Communications, Navigation, & Surveillance

D

DGPS	Differential Global Positioning System
DOD	Department of Defense
DOT	Department of Transportation

E

ECEF	Earth Centered Earth Fixed
EXCOM	Executive Committee

F

FAA	Federal Aviation Administration
FAATC	Federal Aviation Administration Technical Center
FANS	Future Air Navigation System
FAR	Federal Aviation Regulation
FDMA	Frequency Division Multiple Access
FMS	Flight Management System

G

GA	General Aviation
GAO	General Accounting Office
GES	Ground Earth Station
GLONASS	Global Orbiting Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System

H

HF	High Frequency
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I

ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
INMARSAT	International Maritime Satellite Organization
IOC	Initial Operational Capability
IRS	Inertial Reference System

K

Kg	Kilogram
Km	Kilometer

L

LAAS	Local Area Augmentation System
LADGPS	Local Area Differential GPS
LORAN-C	Long Range Navigation-C

M

MASPS	Minimum Aviation System Performance Standards
MHz	MegaHertz
MIT	Massachusetts Institute of Technology
MLS	Microwave Landing System
MOPS	Minimum Operational Performance Standards

N

NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NOTAMS	Notice to Airmen
NTSB	National Satellite Test Bed

O

OMB	Office of Management and Budget
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P

P-Code	Precise Code
P3I	Pre-Planned Product Improvement
PM	Program Manager
Pos/Nav	Positioning/Navigation
PPS	Precise Positioning Service

R

R & D	Research and Development
RAIM	Receiver Autonomous Integrity Monitor
RF	Radio Frequency
RFP	Request for Proposal
RMS	Root Mean Square
RNP	Required Navigation Performance
RTCA	RTCA, Inc. (Formerly Radio Technical Commission for Aeronautics)

S

SA	Selective Availability
SARPS	Standards and Recommended Practices
SATNAV	Satellite Navigation

SCAT	Special Category
Sig Gen	Signal Generator
SNC	Satellite Navigation Center
SOIT	Satellite Operational Implementation Team
SPIT	Satellite Procedures Implementation Team
SPO	Satellite Program Office
SPS	Standard Positioning Service
SU	Soviet Union

T

3D	Three Dimensional
TERPS	Terminal Instrument Procedures
TSARC	Transportation Systems Acquisition Review Council
TSO	Technical Standard Order

U

US	United States
UTC	Coordinated Universal Time

V

VHF	Very High Frequency
VOR	Very High Frequency Omnidirectional Range

W

WAAS	Wide Area Augmentation System
WADGPS	Wide Area Differential Global Positioning System
WES	WAAS Environmental Simulator
WGS	World Geodetic Survey
WIB	Wide Area Integrity Broadcast
WMS	Wide Area Monitor Station
WG	Working Group
WPI	Worcester Polytechnic Institute
WRS	Wide Area Reference Station