DRAFT

AIR FORCE SPACE COMMAND

CAPSTONE REQUIREMENTS DOCUMENT

FOR

GLOBAL POSITION, VELOCITY, AND TIME DETERMINATION CAPABILITY

18 JULY 1997
Supersedes: 23 JUNE 1997

DRAFT
Not for Implementation or Compliance

OPR: HQ AFSPC/DR
Phone: Comm (719) 554-5720
DSN 692-5720

DRAFT

DRAFT

TABLE OF CONTENTS

SECTION 1

1. GENERAL DESCRIPTION OF OPERATIONAL CAPABILITY

1.1 INTRODUCTION

1.1.1 The Global Position, Velocity, and Timing Determination

The capability to precisely determine position, velocity, and time (PVT) is extremely valuable for military missions and civil and commercial applications. Globally, such systems include the Global Positioning System (GPS), air traffic control facilities, aviation and maritime navigation aids, various precise time distribution systems, and many others. Although there are foreign systems that provide PVT information to United States (US) military and civil users, such systems will not be relied upon for military operations. Because of its national and international importance, as well as pervasive use, policies and guidance with respect to the GPS provide a foundation for defining overall requirements. Requirements are stated in terms of performance and no particular solution, either ground-based or space-based, is recommended or implied.

1.1.2 Presidential Decision Directive

The combination of individual ground-based and space-based systems that provide PVT services to military and civil users can be viewed as a global PVT "system of systems". Although many widely dispersed systems provide PVT services, GPS has emerged as the dominant element of this global system of systems. Recognizing this, in March 1996, the President approved a comprehensive national policy, the Presidential Decision Directive (PDD) on the management and use of GPS, "US Global Positioning System Policy," (National Science and Technology Council-6 (NSTC)-6)). This policy presents a strategic vision for management and use of GPS, addressing a broad range of military, civil, commercial and scientific interests, both national and international.

1.1.2.1 Goals of the PDD. The directive states US goals as follows:

a. Strengthen and maintain our national security.

b. Encourage acceptance and integration of GPS into peaceful civil, commercial and scientific applications worldwide.

c. Encourage private sector investment in and use of US GPS technologies and services.

d. Promote safety and efficiency in transportation and other fields.

e. Promote international cooperation in using GPS for peaceful purposes.

f. Advance US scientific and technical capabilities.

1.1.2.2 PDD Policy Guidelines. Within these broad goals, the PDD established the following policy guidelines:

a. We will continue to provide the GPS Standard Positioning Service (SPS) for peaceful civil, commercial, and scientific use on a continuous, worldwide basis free of direct user fees.

b. It is our intention to discontinue the use of Selective Availability (SA) within a decade in a manner that allows adequate time and resources for our military forces to prepare fully for operations without SA. To support such a decision, affected departments and agencies will submit recommendations in accordance with the reporting requirements outlined in this directive.

c. The GPS and US Government (USG) augmentations will remain responsive to the National Command Authorities.

d. We will cooperate with other governments and international organizations to insure an appropriate balance between the requirements of international civil, commercial, and scientific users and international security interests.

e. We will advocate the acceptance of GPS and USG augmentations as standards for international use.

f. To the fullest extent possible, we will purchase commercially available GPS products and services that meet USG requirements and will not conduct activities that preclude or deter commercial GPS activities, except for national security or public safety reasons.

g. A permanent interagency GPS Executive Board (IGEB), jointly chaired by the Department of Defense (DoD) and Department of Transportation (DOT), will manage the GPS and US Government augmentations. Other departments and agencies will participate as appropriate. The IGEB will consult with USG agencies, US industries and foreign governments involved in navigation and positioning system research, development, operation and use.

1.2 PURPOSE

This capstone requirements document (CRD) responds to the National objectives and policy guidelines detailed in the PDD and consolidates military and civil needs for PVT services. These requirements reflect the USG vision of an overarching PVT capability for applications in national security, space operations, space exploration, safety, communications, transportation, environmental sensing, and other areas.

The CRD will be used as a basis for development of military and civil system-specific operational requirements documents (ORDs) for specific applications. This CRD consolidates requirements from military departments, civil departments, and commercial interests. For the DoD, it is a bridge between multiple mission need statements (MNS) and Service ORDs. For the civil communities (government and private), it is a bridge between strategic plans and individual system specifications. The CRD is also intended to be used as a source document for developing future worldwide PVT system architecture alternatives.

1.3 SCOPE AND PROCESS

1.3.1 Scope

This CRD contains performance-based requirements for development of future PVT systems. Requirements gathered to date have been for near-term and mid-term needs. Far-term military requirements will be addressed in the mission area planning process. Requirements are categorized according to the physical realm in which the user will operate: subsurface (underwater and underground), surface, air, and space.

1.3.2 Process

Requirements changes may occur because of changes in missions, threats, operations concepts, new technologies, or emerging requirements. The source of changes may be military users, civil customers, or inputs from the scientific or commercial communities. When requirements change, the CRD will be updated.

Air Force Space Command (AFSPC) led the effort to develop the CRD. As approved/validated requirements documents, AFSPC used the Chairman, Joints Chiefs of Staff (CJCS) Master Navigation Plan (MNP) and the Federal Radionavigation Plan (FRP) as the major source documents. Applicable MNS and ORD were also used as source documents. In addition, AFSPC solicited and collected requirements from the military services. The DOT solicited and collected requirements from the government, scientific, commercial and other civil communities. As shown in Figure 1-1, Air Force Materiel Command’s Space and Missile Systems Center (SMC), using the CRD, is developing an acquisition master plan (AMP) for GPS modernization that will address GPS-based (i.e., GPS and GPS augmentations, or other systems for which GPS is the primary source of PVT information) solutions to the requirements articulated in the CRD. The process by which those required capabilities that cannot be satisfied by the GPS-based architecture defined in the AMP is to be determined Concepts will be developed, trade-off analyses conducted, and affordability considerations incorporated. The optimal architecture will be recommended to the Joint Space Management Board (JSMB). Concurrently, the Joint Requirements Oversight Council (JROC) will validate DoD requirements. The final architecture will address military and civil applications and will be approved by the IGEB.

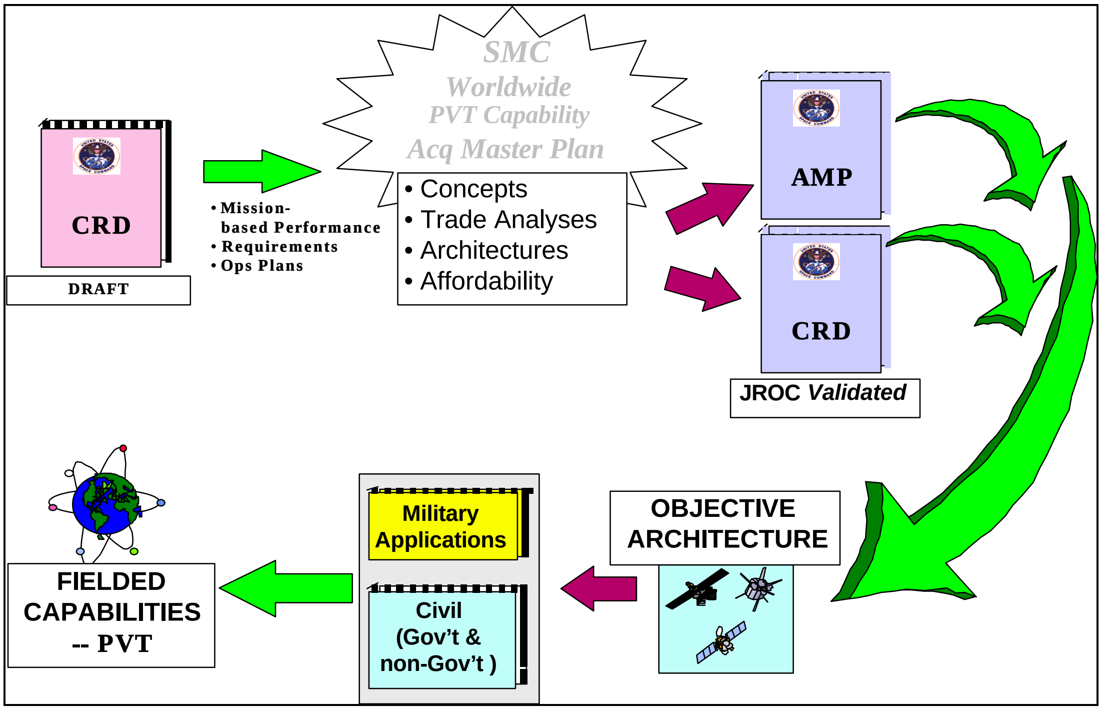

Figure 1-1. Capstone Requirements Document Development Process

The CRD and PVT system architecture will undergo periodic review, revision, and revalidation as shown in Figure 1-2. Costs, benefits, and implementation issues of proposed architectures will be identified by trade-off studies. Affected users of the PVT systems will provide input on the new requirements and architecture. The DoD Space Architect, as well as the IGEB, will review the CRD. The JROC will validate all new or modified military requirements. The JSMB has oversight responsibility for military space-based architectures. Funding needed for the selected architecture will be addressed in the DoD Planning, Programming, and Budgeting System (PPBS) and modifications to acquisition plans. As designated in the PDD, the IGEB has overall responsibility for managing GPS and its US augmentations, and will be the final approval authority for all significant changes to the architecture.

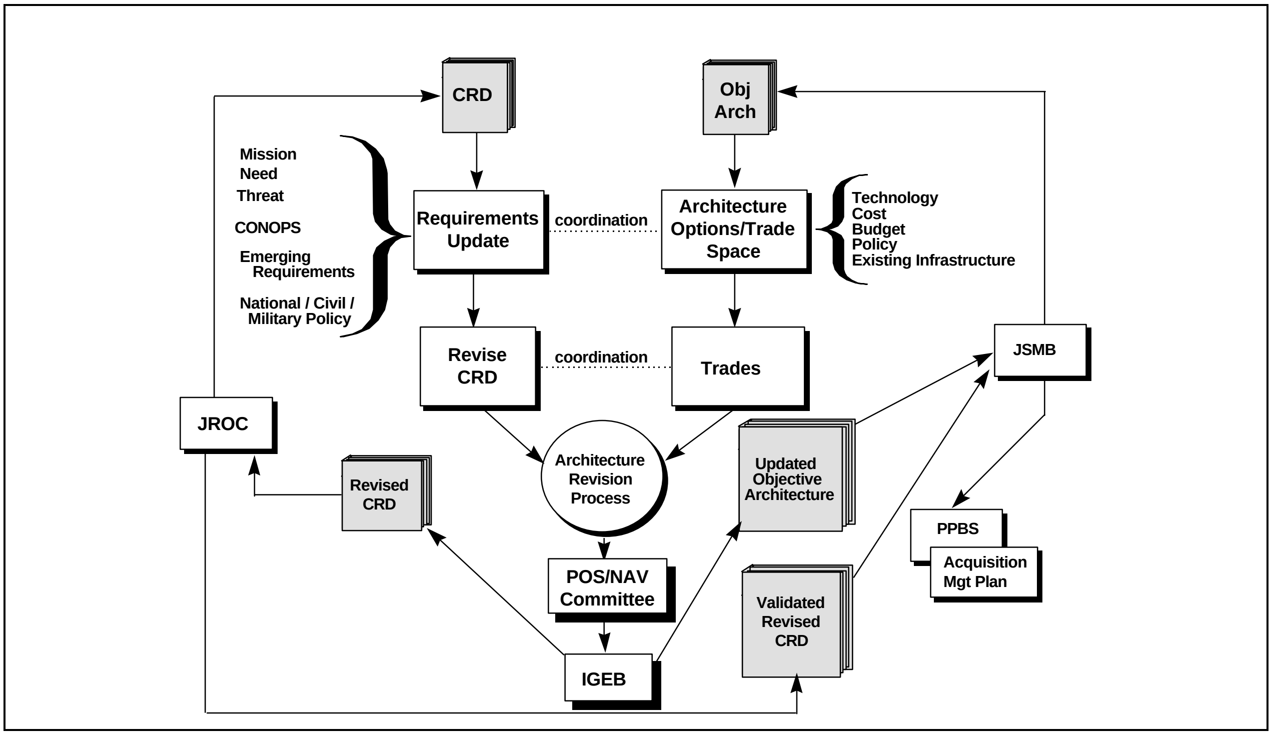

Figure 1-2. CRD Update and Review Process

1.4 PVT BACKGROUND AND GUIDANCE

1.4.1 Position, Velocity, and Timing Descriptions

1.4.1.1 Position. Position is defined in Webster's Ninth New Collegiate Dictionary as the point or area occupied by a physical object. The objective of the position determination capability is to improve the effectiveness of military and civil missions and activities by enhancing their ability to precisely determine their position below, on or above the surface of the earth 24 hours a day. Positioning provides information on the user's location relative to a specific geospatial reference coordinate system at an accurately specified time. User equipment tailored to specific applications determines the user location in the appropriate format. Augmented processing of PVT position information or supplementary information may be necessary to meet the required accuracies.

1.4.1.2 Velocity. Velocity is defined by Webster as the time rate of linear motion in a given direction. The objective of the velocity determination capability is to improve the effectiveness of military, civil, and commercial missions and activities by enhancing their ability to safely and effectively navigate worldwide, 24 hours a day. Velocity is a derived capability determined by measuring the Doppler shift of a signal.

1.4.1.3 Timing. Time is a quantity used to specify the order in which events occurred and measure the amount by which one event preceded or followed another. Joint Publication 1-02, DoD Dictionary of Military and Associated Terms, defines time as the designation of an instant on a selected time scale, astronomical or atomic. Timing services, with varying degrees of precision, are required by numerous military and civil systems in support of many critical missions. Internationally, coordinated universal time, abbreviated UTC, is maintained by the Bureau International des Poids et Mesures, Sevres, France. The precise time reference for US military systems is UTC as determined by the United States Naval Observatory Master Clock (UTC [USNO]). Several systems are used for distribution of UTC (USNO), including GPS. Maintenance of time interval (precise frequency) is the responsibility of the National Institute of Standards and Technology. Timing is a combination of precise time and time interval.

1.4.2 National Guidance on PVT

In addition to the PDD previously discussed, a White House commission report, recent laws, executive direction, and Federal plans provide a foundation for many of the requirements identified in this document.

1.4.2.1 White House Commission on Aviation Safety and Security. In another important initiative that significantly affects the global PVT system, this Commission, chaired by Vice President Gore, recommended the following GPS actions in its final report to the President:

- The US must provide stronger strategic leadership for civil uses of GPS.
- Strong civilian participation is required in GPS planning and decision making.
- A Civil GPS Users Advisory Council should be established.
- Greater redundancy is needed to enhance the ability of users to cross-check GPS accuracy and verify the system's reliability.
- The GPS Executive Board should resolve the remaining issues over funding and frequency assignment for a second civil frequency.
- The Federal Aviation Administration's (FAA) Wide Area Augmentation System (WAAS) requires two frequencies to meet civil accuracy needs.
- The GPS system must be protected from both intentional and unintentional interference.
- The FAA should identify and justify, by July 1997, the frequency spectrum necessary for the transition to a modernized air traffic control system.
- To ensure the FAA's spectrum needs during modernization are not compromised, the commission recommends that the FAA complete a full justification, NLT July 1997, as well as a plan for freeing up spectrum as older systems are modernized or decommissioned.
- The US Government should ensure the accuracy, availability and reliability of the GPS system to accelerate its use in National Air Space modernization and to encourage its acceptance as an international standard for aviation.

1.4.2.2 Public Law 103-160. Public Law 103-160 (referred to as GPS 2000) directs that after 30 September, 2000, funds may not be obligated to modify or procure any DoD platforms that are not equipped with a GPS receiver. In compliance with this law, GPS receivers are scheduled to be installed in most military platforms by end of Fiscal Year (FY) 2000.

1.4.2.3 The Federal Radionavigation Plan. The 1994 FRP delineates policies and plans for Federally-provided radionavigation services. This plan describes areas of authority and responsibility and provides a management structure by which the individual operating agencies can define and meet radionavigation requirements in a cost-effective manner. The FRP identifies military, space, civil air, civil marine, and civil land radionavigation requirements. It is the official source of radionavigation policy and planning for the Federal Government. The document is published jointly by the DoD and the DOT. The most current edition was published in 1995. A new version is in draft form.

1.4.3 DoD Guidance on PVT

The CJCS approved the most recent MNP in 1994 (CJCS Instruction 6130.01). This plan, currently under revision, implements DoD Positioning and Navigation (POS/NAV) policy, validates military positioning/navigation requirements, compares requirements to existing technology, identifies performance shortfalls, highlights needed research and development, and provides long-term projections of anticipated capabilities. It serves as the basis for the Services and DoD agencies for programming and budgeting for positioning/navigation systems. This plan is the DoD input to the FRP and appropriate North Atlantic Treaty Organization plans.

1.4.4 Significant Studies and Reports

Explosive growth in commercial and scientific use of GPS has brought this PVT system to the forefront. More efficient land, sea, and air transportation programs have been enabled by using GPS in conjunction with expanding communication technologies. In addition, the number and types of other innovative applications has rapidly increased. As a result, numerous studies and reports have been done with respect to future plans for GPS and its augmentations. Several long-range military studies also have been published emphasizing the essentiality of accurate and reliable PVT information to win future wars. Some of the most significant of these are discussed below. Additional references are listed in Appendix D.

1.4.4.1 Joint Vision 2010. Published by the Organization of the Joint Chiefs of Staff in 1997. This vision of future warfighting embodies the improved intelligence and command and control available in the information age. The document goes on to develop four operational concepts: dominant maneuver, precision engagement, full dimensional protection, and focused logistics. It creates a template to guide the transformation of these concepts into joint operational capabilities. With respect to PVT capabilities in the 21st Century, the document specifically discusses the high value of "knowledge of the precise location of dispersed friendly forces" and "precision engagement" to "enable greater discrimination in the application of force."

1.4.4.2 The "Global Positioning System, Charting the Future" Study. This is an independent committee's report, published May 1995, under the joint auspices of the National Academy of

Public Administration and the National Research Council. The report addresses the future management and funding of the GPS program as mandated by the National Defense Authorization Act for FY 1994. Key areas for GPS (commercial, civil, government, and international) were examined as well as paramount national security interests.

1.4.4.3 "A Technical Report to the Secretary of Transportation on a National Approach to Augmented GPS Service". This report contained the findings of a joint Department of Transportation and Department of Commerce study published in December 1994. The study evaluated the capabilities of various means of GPS augmentation and recommended the optimum integrated system for meeting the requirements of Federal land, marine, aviation, and space users.

1.4.4.4 "The Global Positioning System: Assessing National Policies," 1995. This report documents a Rand Corporation Study. The study identifies opportunities and vulnerabilities for US interests caused by GPS. It also makes policy recommendations.

1.4.4.5 Spacecast 2020, June, 1994, Air University. This study identified capabilities for the period 2020 and beyond and the enabling technologies that will support the security interests of the US.

1.4.4.6 Air Force 2025, "America's Vigilant Edge", Air University, 1996. Directed by the Chief of Staff, USAF, this study looks 30 years into the future to identify the concepts, capabilities and technologies the US will require to remain the dominant air and space force in the 21st century.

1.4.4.7 New World Vistas Air and Space Power for the 21st Century, Space Applications Volume, Science Advisory Board, December, 1995. This report emphasizes the long-term military need for highly accurate positioning and time transfer capabilities.

1.5 OPERATIONAL CONCEPT

1.5.1 Scope

The operations concept describes how an operational capability, consisting of a system-of-systems, may be employed. This section describes the military, GPS, protection and prevention, space, and civil PVT operations concepts. It closes with a discussion of future PVT systems operations concepts.

1.5.2 Military Operational Concepts

In accordance with National Military Strategy and Joint Vision 2010, the operational objective for the US Military is to achieve overwhelming effect in a compressed time to win future conflicts quickly, decisively, and with few casualties. This will be achieved through domination of the adversary by outmaneuvering enemy forces and destroying them with precise, concentrated firepower. US forces will seek to control the extent and pace of the battle, while also disrupting the adversary's decision cycle. Furthermore, US forces are often called upon to execute other operations in the lower end of the spectrum of conflict that range from humanitarian assistance to peace-keeping and peace making. To achieve these objectives, it is necessary to orchestrate and synchronize a complex set of sensors; forces; precision weapons; command, control, communications, computers, and intelligence (C4I); and information warfare (IW) capabilities within the tactical and strategic battlespaces. PVT information is absolutely critical to this concept. Without highly capable and protected PVT, complex battlespace interactions and weapons delivery cannot be executed. PVT systems provide essential force enhancement capabilities to several warfighting functions as shown in Table 1-1. The functions were adapted from the Universal Joint Task List, Version 3.0, CJCSM 3500.04A, 13 September, 1996.

1.5.2.1 PVT Operations Concept. The worldwide multiplicity of uses of PVT systems requires a highly accurate capability that is available to all users. Future PVT systems will provide position accuracy, velocity accuracy, and timing accuracy that meets the most stringent requirements for all users. The PVT systems will meet all but the most stringent integrity, availability, and continuity of service requirements without augmentation. Military and civil demands for PVT availability, accuracy, and coverage are expected to continue to increase. As recommended in the Gore Report, the US will gradually transition from dependence upon ground-based navigation aids. GPS meets or exceeds the accuracy, availability and coverage of many other radionavigation systems. Consequently, as the full civil potential of GPS is realized the Federal Government expects to phase out radionavigation systems that no longer will be required. See Section 3 for a detailed discussion of current systems capabilities, phaseout dates, etc.

PVT information will be needed by US and allied forces in stressed environments, including electronic jamming. Hostile forces must not be able to use PVT capabilities or any augmentations in any area of responsibility (AOR) in which US and allied forces operate The civil community will be able to use PVT capabilities outside the specified AOR.

While PVT systems will provide robust capabilities, the key to effective use of the system will be embedded user equipment (UE) capabilities. UE with a wide range of capabilities will be employed. For example, some UE may be capable of providing highly accurate position information, yet have no antijam (AJ) capability. New PVT systems will optimize the performance of existing (legacy) UE.

1.5.2.1.1 Scenarios.

a. Peacetime: All users receive the same service, with accuracy largely dependent on the capabilities of the UE. Service is comparable to today's GPS SPS without SA.

b. Small Scale Contingency: There would be basically no change in operation except the US would prevent adversaries in the AOR from having access to the full precision of the PVT system. There would be minimal effect on users outside the AOR.

c. Major Theater War: The US would prevent adversaries in the theater from having access to the full precision of the PVT system. Depending on the threat, the US might also deny theater adversaries any use of the PVT systems, while ensuring disruptions outside the theater are minimized. The US would also ensure effects on friendly users near the theater are minimized. At the same time, friendly users would continue use of the PVT systems through inherent PVT system interference resistance and the capability to continue operations while denying use to adversaries.

Table 1-1: Growing Information Requirements

Warfighting Functions	Capabilities Required	PVT Contribution
Command and Control/ Collaborative Planning/ Battle Management	• Flexible, high capacity Command & Control Networks • Interactive Data Networks and Distributed Databases • Video Teleconferencing • Maneuver Control and Situational Awareness • Fratricide Prevention	Timing Position
Intelligence	• Intelligence data collection and dissemination • Imagery and related products • Terrain Visualization; Maps-Charts-Geodesy • **High Precision Positioning**	Position Position Position
Precision Strike	• **High Precision Navigation** • Mission data and target/threat updates • Cooperative Engagement • Remote Operations	Velocity Position Timing
Theater and Strategic Warning and Surveillance	• Missile Warning • Reconnaissance, Acquisition, Targeting	Position/Timing Position/Timing
Environmental Data	• Weather and oceanographic reports • Other environmental data	Position/Timing
Training and Planning	• War-game/simulation; Course of Action analyses • Proficiency training and Mission Rehearsal/Preview	
Sustainment support: • Logistics • Personnel • Finance • Contracting	• "Reachback" of deployed forces to the sustaining base • Telemedicine • Distributed Databases and Networks • In-Transit Asset Visibility	Timing Timing Position

1.5.2.2 Protection and Prevention Operations Concept. The ability to protect PVT information for friendly use while preventing it hostile exploitation is critical to military operations. Recognizing this fact, Congress directed the DoD in the FY96 Defense Authorization Act, to implement a plan for the enhancement of GPS that provides for the:

- Development and acquisition of effective capabilities to prevent hostile military forces from using the GPS without hindering the ability of US military forces and for civil users to have access to and use of the system.

- Development and acquisition of receivers for the GPS and other techniques for weapons and weapon systems that provide substantially improved resistance to jamming and other forms of electronic interference or disruption.

In addition, the PDD discussed earlier stated that the DoD will "develop measures to prevent the hostile use of GPS and its augmentations to ensure that the US retains a military advantage without unduly disrupting or degrading civilian uses."

These directives will be operationally implemented as part of the protection and prevention initiative. Protection and prevention operational actions taken to modify satellite modes or signal characteristics via satellite control will be accomplished by AFSPC. Protection and prevention actions such as jamming of enemy receivers or modification to user equipment will be performed by in-theater forces.

1.5.3 Use of Foreign PVT Systems.

US military and civil aircraft use foreign PVT systems on a routine basis while operating in the air space of foreign countries. This is in accordance with International Civil Aviation Organization (ICAO) rules and will continue. These systems are primarily local in their coverage and are protected by international agreements. Foreign space-based systems, such as the Russian Global Orbiting Navigation Satellite System (GLONASS), have much broader coverage and potentially could be used for a wide variety of PVT needs. In this context, at least for civil applications, GLONASS could be viewed as "competing" with GPS for worldwide acceptance and usage. As a practical matter, users may be able to choose one system over another or even choose a combination of systems. US policy is to promote GPS as the world standard by committing to long-range assurance of signal availability and incorporating improvements as technology and funding permit. Military users may use foreign systems in planned or opportunistic scenarios, for example, in an area where the foreign system might offer better coverage. However, US military users will not rely on foreign systems in a hostile or potentially hostile environment. A brief description of the major foreign space-based PVT systems is provided below.

1.5.3.1 Global Navigation Satellite System. GLONASS provides navigation information primarily for maritime and air navigation, although its time transfer capabilities are similar to those of GPS. The system was inaugurated in 1982. About 67 satellites were launched between 1982 and 1994, apparent evidence that the satellites suffer a higher attrition rate than GPS satellites. The GLONASS constellation comprises 24 satellites, eight in each of three orbital planes, separated by 120 degrees. This configuration allows users access to at least four satellites.

Each GLONASS satellite transmits two spread spectrum signals in the L band and operates on, and can be identified by, a different set of frequencies. The radio frequency (RF) carriers operate between 1240 megahertz (MHz) and 1260 MHz and between 1597 MHz and 1617 MHz. Unlike

GPS, all the GLONASS satellites transmit the same code. The GLONASS satellites transmit a low precision, narrow band code (similar to GPS SPS) on the higher transmit frequency and a high precision, broad band code (similar to GPS precise positioning service (PPS)) on both frequencies. A low speed (50 Hz) navigation message from each satellite includes precise ephemeris for that satellite and information about the onboard clock, as well as almanac data about the other GLONASS satellites. There is no counterpart to Selective Availability in GLONASS.

1.5.3.2 European Geostationary Navigation Overlay Service. The European Geostationary Navigation Overlay Service (EGNOS) is an augmentation system for satellite navigation. EGNOS is being jointly developed by the European Space Agency, the European Commission, and the European Organisation for the Safety of Air Navigation (EuroControl). EGNOS will provide civil GPS and GLONASS users with improved accuracy, integrity, and availability. One transponder will be carried on each of two INMARSAT-III satellites, located above the equator at 64 degrees east and 15.5 degrees west longitude. Transponder coverage will include Europe, Africa, South America, and most of Asia.

EGNOS will provide ranging, integrity, and Wide Area Differential Services. The ranging service will broadcast GPS-like navigation signals to help solve the shortfall in GPS/GLONASS satellite visibility. Ranging service is planned to start in 1997. The integrity service will broadcast range-error estimates for each GPS, GLONASS, and EGNOS navigation signal. The integrity service enables users to decide much sooner whether the signal from a particular navigation satellite is out of tolerance. The Wide Area Differential Service will broadcast correction signals to improve the precision of GPS SPS to a precision of five to ten meters. The integrity service and Wide Area Differential Service will be phased in between 1998 and 2000.

The initial INMARSAT-III transponders will be supplemented at a later time. Ranging and integrity monitors will be distributed over the service area and connected with Master Control Centers, where the EGNOS signal will be generated.

1.5.3.3 Japanese GPS Service. Japan is developing its own four satellite GPS augmentation constellation and hopes to have it operational by 2000. In the meantime, the Japan Civil Aviation Bureau (JCAB) and the FAA have agreed that a Multi-function Transport Satellite (MTSAT) will offer WAAS services in the Asian-Pacific region. The MTSAT will offer air-to-ground communications, WAAS-compatible satellite navigation services, and meteorological imaging and sensor services. The first MTSAT is scheduled for launch in 1999. The JCAB plans to offer leased MTSAT service to countries in the Asian-Pacific area.

1.5.4 Space Exploitation Operational Concept.

PVT may be used for space platform (i.e., satellite and space exploration) navigation by providing a means for ephemeris determination, attitude determination, and time transfer. This use of PVT is expected to increase in the future, both in numbers of platforms and orbital altitudes, from low earth orbit to geosynchronous. Space-based applications of PVT are considered “out-of theater” uses and the impact of protection and prevention actions on such uses must be accounted for in design of protection and prevention devices.

1.5.5 Concept of Operations for Civil Applications

The civil, commercial, and scientific sectors have all seen rapid growth in the use of GPS. Some of the myriad civil uses of GPS are listed in Table 1-2. The operational concept for these areas is for independent, distributed users to have free access to the civil PVT signals. Characteristics of the civil signal will be openly published. Signal reliability, availability, and integrity will be provided at assured levels. Determining PVT signal applications is the responsibility of the user.

Table 1-2: Examples of Civil Uses of GPS

MAJOR AREA	USES				
LAW ENFORCEMENT AND SAFETY	• Dispatch of ambulance, police and fire department personnel and equipment • Orienteering/Personal Navigation	• Monitoring of game preserves and protected fishing grounds • Emergency evacuation planning	• Improved emergency response time • Monitoring of severe weather • Tracking/recovery of stolen vehicles	• Tracking movement of contraband • Security of high government officials and dignitaries while traveling	• Border surveillance • Flood level and damage assessment • Locating disabled vehicles for road services
AVIATION	• Precision and non-precision all-weather approaches (WAAS) • Monitoring of wing deflection in flight • In-flight monitoring of position/location	• Precise airfield and landing aid to all airports, regardless of development • Direct routing for aircraft fuel savings • LAAS	• Local, national and international en-route navigation • Wind shear detection • Search and location of downed aircraft	• Closer aircraft separation standards for more efficient air traffic management • Seamless (global) air space management	• Airport surface traffic management • Less expensive/more accurate avionics • Enhanced Loran C in-flight navigation
MARITIME AND WATERWAYS	• Navigation on the high seas • Positioning of buoys and nav-aids • Monitoring deflections in dams	• Search and rescue • Location of commercial fishing traps and nets • Monitoring icebergs and rouge flows • Coastal Navigation	• All weather harbor navigation approach • Harbor facility management • Precision ice breaking operations	• Vessel traffic services • Enhanced Loran C marine navigation • Observing tides and currents	• Dredging of harbors and waterways • Offshore drilling research • Oceanic research
COMMUNICATIONS	• Precise timing for interfacing messages • Validation of information transmission • Network management and control	• Wide-area synchronization of high-speed networks • Differentiation of wireless mode: cordless, cellular, satellite, etc.	• Mobile use position determination for paid linking to PCS • National Spatial Data Infrastructure	• Tagging of information for time-delayed transfer to data ports • Personal navigation and reporting	• Stochastic networking among cooperative mobile platforms • US/Global Information Infrastructure
ENVIRONMENTAL PROTECTION	• Ground mapping of ecosystems • Oil spill tracking and clean-up • Mapping of contaminated sediments in harbors & rivers • Distribution of ecosystems contaminants	• Hazardous waste site investigation • Monitoring of natural gas pipelines • Ground water level elevation • Criminal investigation of illegally buried hazardous waste	• Mapping of sub-surface contamination • Tracking of migratory animals • Boundaries of catchment basins, sludge lagoons, tailing areas	• Sudden alert for stored hazardous materials moved without consent • Precise navigation to sampled points • Location of sites, wells, storage tanks, outfalls	• Precise location of stored hazardous materials • Precise location of sampling points • Location of pesticide-contaminated homes • Ground mapping of wellhead, source-water protection areas
MINING, EXCAVATION, AND CONSTRUCTION	• Electronic marking of geological events	• Accurate stockpile record keeping	• Precision location for mining explosives	• Robotic mining & excavation	• Subsidence monitoring & reclamation
PUBLIC TRANSPORTATION	• Bus fleet on-the-road management	• Railroad fleet monitoring	• Train control and collision avoidance	• Improved operator/passenger security	• Personal safety
RECREATION AND SPORTS	• Hiking and mountain climbing • Electronic compassing for orientation	• Measuring at sports events • Finding historic locales in wilderness	• Relocating favorite fishing spots	• Setting lines on sports fields	• Wilderness search and rescue
FORESTRY AND AGRICULTURE	• Forest area and timber estimates • Fire perimeters	• Identifying species habitats • Water resources	• Unmanned (robotic) harvesting • Wildlife tracking	• Precision crop dusting by aircraft • Ground subsidence, erosion, & surveillance	• Precise plowing, planting and fertilizing
GROUND TRANSPORTATION	• Intelligent Transportation System - IVHS • Highway facility and maintenance • In-vehicle wireless voice systems	• Improved emergency services • Accident location studies • Monitoring status of bridges	• Vehicle position/location for navigation tracking and monitoring • Highway construction • Guidance for robotic systems	• Special travel information • Truck fleet on-the-road management • Stereosonic navigation for the blind • Recording of truck travel across state lines for automatic tax billing	• Vehicle control systems: position, location and velocity • "You are Here" mapping displays
SCIENCE, TECHNOLOGY AND SPACE	• Measurements of sea level from satellites • Measuring river flood crests • Spacecraft attitude control	• Navigating of space shuttles • Measuring atmospheric water vapor from the ground	• Placing satellites into orbit • Precise global mapping of the ionosphere • Atmospheric temperature profiling	• Monitoring earthquakes and tectonic plates • Users weather balloon position radiosonde • Weather and climate modeling	• Measuring ground subsidence • Precise atomic laboratory timing
SURVEYING AND MAPPING	• Electronic bench marking for absolute latitude, longitude and altitude • Oil and mineral prospecting	• Single-handed high precision surveys • Measuring and recording of property boundaries • Deformation engineering surveys	• Hydrographic surveying • Real time DPS with regional point network reference stations • Industrial surveying • Robotics manufacturing	• Roadway profiling with kinetic GPS integration with GIS for more reliable mapping and data collection	• Area measurement without triangulation • Efficient and accurate photo surveys • National Spatial Data Infrastructure
HEALTH CARE	• Tracking disease spread/distribution • Precise timing in med-lab tests	• Epidemiological mapping	• Immediate position/location of medical personnel and specialists	• Personal navigation for blind persons	• Analytical medical modeling

Source: US GPS Industry Council and user input

1.5.6 Future PVT Operations Concept

To successfully implement military and civil operational concepts, growing PVT needs in all operating environments - land, sea, subsurface, air, and space - must be met. Users must be able to develop and execute plans without PVT constraints. To provide the needed PVT capability, the USG may rely on a variety of systems, including space-based, terrestrial, and user specific, each with its own operations concept.

1.6 PVT MISSION AREAS AND MISSION NEEDS

1.6.1 PVT Mission Areas for DoD

This CRD supports the DoD mission areas identified in the latest listing published by the Under Secretary of Defense for Acquisition and Technology and shown in Table 1-3. The primary mission area for PVT, "#357 Navigation and Position Fixing," is highlighted. Timing is not a numbered mission area, but should be considered for addition.

Table 1-3: DoD Mission Areas Supported by PVT

MISSION AREA	MISSION AREA TITLE	MISSION AREA	MISSION AREA TITLE
TBD	Precision Timing	307	Special Operations Forces
110	Strategic Offense	340	Theater and Tactical Programs
210	Land Warfare	342	Surveillance and Warning
214	Ground Based Anti-Air and Tactical Missile Defense	350	Navigation/Warfare C2
215	Land Warfare Support	351	Land Warfare C2
220	Air Warfare	352	Air Warfare C2
225	Air Warfare Support	353	Naval Warfare C2
230	Naval Warfare	**357**	**Navigation and Position Fixing***
261	Inter-Theater Airlift	370	Electronic Combat
262	Inter-Theater Sealift	400	Defense-Wide Mission Support
263	Intra-Theater Airlift	410	Space Launch Orbital Support
300	Command, Control, Communications, and Intelligence Programs	998	Counter-Narcotics

* Primary mission area

1.6.2 PVT Mission Areas for Other Federal Agencies.

GPS has become a "public utility" for many civil uses and a critical component of the Global Information Infrastructure.

The DOT requires a PVT capability to assist civil aeronautical, maritime, and terrestrial navigators, to improve safety and efficiency while minimizing environmental impacts of the nation's transportation infrastructure. Other Federal agencies require PVT capabilities for geodesy, oceanography, meteorology, seismic monitoring, space navigation, and geographic information systems development.

1.6.3 Mission Areas for Other Entities

State and local governments and many private industries also use PVT services to improve productivity and introduce new services supporting economic growth and international competitiveness.

Increasing private sector involvement has affected the evolution of the FRP. The PVT system must ensure, in accordance with the national policy found in OMB Circular A-76, that the private sector is considered in the design, development, installation, operation, and maintenance of all equipment and systems required to provide common-use radionavigation aids in support of the FRP (within the constraints of national security).

1.6.4 Mission Needs

1.6.4.1 Related Activities. The DoD and other agencies have several ongoing PVT-related initiatives and programs. For the Air Force, the major initiative is the Global Access, Navigation, and Safety (GANS) effort. Figure 1-3 illustrates some of the interrelationships between Air Force programs that fall under the GANS umbrella and those that relate to PVT systems. Some of the programs, initiatives, and recommendations are interrelated, while others are not. Some of the initiativess, such as protection and prevention and GPS 2000, involve other Services or DoD agencies, so do not entirely fall under GANS.

As Figure 1-3 further illustrates, there are major initiatives outside the DoD that will also affect future PVT requirements and programs. The widespread—and rapidly growing—civil use of GPS will certainly drive new requirements. New international civil air rules, leading to "free flight" will also impact PVT requirements worldwide. The Report of the White House Commission on Aviation Safety and Security (Gore Report) will also impact PVT systems (see paragraph 1.1.3). All PVT related programs and associated acquisitions should be closely coordinated by DoD and DOT to avoid duplication of effort.

The Worldwide Navigation ORD will contain the subset of military, commercial, and civil PVT requirements to be fulfilled specifically by the GPS. The Protection and Prevention ORD will include military requirements for ground or air-based protection and prevention systems. For implementing GPS 2000, incorporating GPS capabilities in military platforms will be included in each system's ORD or program document. Finally, the GANS CRD will contain the complete set of GANS requirements, including stand-alone systems, as well as space system requirements contained in the GPS ORD.

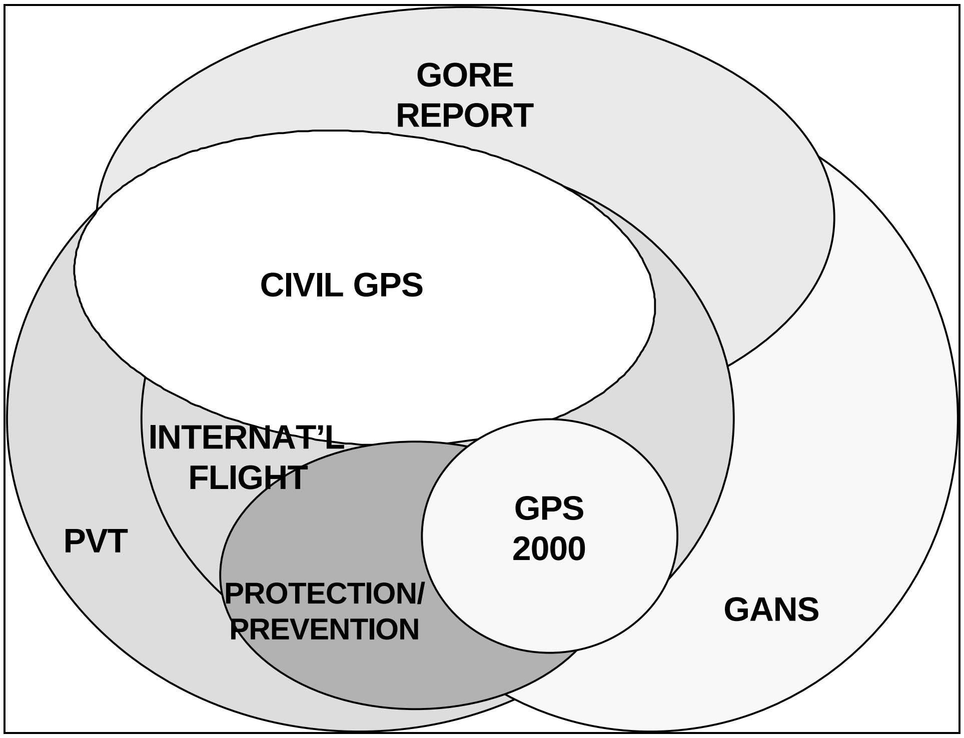

Figure 1-3. Relationship of Position, Velocity & Timing System Requirements and Various Safety and Navigation Programs

1.6.4.2 Related Requirements Documents and Plans. The MNSs, CRDs, ORDs and plans listed below are the primary sources of PVT shortcomings stated in Section 3 and requirements stated in Section 4. Additional requirements have been identified in the CRD process by requirements solicitation and collection by AFSPC and DOT.

1.6.4.2.1 Air Force Space Command MNS 003-92 for an Improved Worldwide Navigational Positioning System, 28 Apr 1993. This MNS identifies a need for continued global navigation and improved accuracy and timing. According to the MNS, existing systems do not meet all DoD requirements as established in the FRP and the CJCS MNP.

1.6.4.2.2 Air Combat Command MNS 003-95 for Operational Protection and Prevention of Global Space-based Navigation Systems, 27 Sep 1995. This MNS identifies a mission-based need to protect the ability of US military forces to use the GPS, to prevent adversaries from using the GPS, and to allow the civil community access to the GPS outside a specified area of responsibility.

1.6.4.2.3 AFSPC Space Information Dominance Mission Area Plan, 17 Dec 1996. This mission area plan consolidates long-range planning for five space-related mission areas. The mission need analysis documented by the plan identifies deficiencies in the navigation mission area. Deficiencies were noted in availability, integrity, accuracy, security (ability to protect a military advantage in navigation systems), control segment robustness, and integration of GPS navigation capability into military weapon systems.

1.6.4.2.4 Army Signal Center ORD for the GPS Tactical Receiver, 24 March 97. This ORD documents the Army's need for GPS receivers to replace obsolete equipment and to satisfy requirements created by digitization of the battlefield. It also represents a step toward implementing GPS 2000 within the Army.

1.6.4.2.5 Air Mobility Command CRD 001-97 for Global Air Traffic Management, Revision 1, 12 May 1997. This CRD represents an initial military step to implement concepts known as Communication, Navigation, Surveillance/Air Traffic Management (CNS/ATM) in the civil aviation community. Since DoD operations encompass the world, the term Global Air Traffic Management was chosen. The CRD documents a need for an avionics suite of communications, navigation, and surveillance equipment to enable "free flight" of aircraft. Free flight is the ability of aircraft to choose own routes, speeds, and altitude in real time.

1.6.4.2.6 Air Force Flight Standards Agency ORD I for Joint Precision Approach Landing System (JPALS), 15 Oct 1996. This ORD followed the Joint MNS for Precision Approach and Landing Capability, validated by the JROC on 29 Aug 95. It states detailed requirements for a next generation precision approach and landing system. The capability described will provide joint operational capability for US forces to perform assigned conventional and special operations from fixed base, shipboard, tactical, and austere environments under a wide range of meteorological conditions.

1.6.4.2.7 Air Mobility Command MNS for Required Navigation Performance (Draft), Undated. This MNS is being generated to enable Air Mobility Command to operate its aircraft in airspace where required navigation performance (RNP) standards will apply.

1.6.4.2.8 CJCS Master Navigation Plan, 20 May 1994. See Section 1.4.3 above.

1.6.4.2.9 1994 Federal Radionavigation Plan, May 1995. See Section 1.4.2.3 above.

1.7 REQUIREMENTS ALLOCATION

This CRD describes many requirements that most likely cannot be met by a single system. Multiple ORDs are anticipated to be developed from this CRD to allocate these requirements to specific systems for development and procurement. While the user and acquisition communities will determine architectures and allocate requirements to specific ORDs, the allocation of those requirements to specific ORDs is beyond the scope of the CRD. In order to ensure all requirements are satisfied, the AMP should contain a mechanism to trace requirements from the CRD to specific ORDs.

1.8 DESCRIPTION OF REQUIRED CHARACTERISTICS

Future PVT system-of-systems will support the mission areas by providing the requisite position accuracy, velocity accuracy, timing accuracy, integrity, availability, coverage, supportability, security, survivability, interoperability, and affordability. The system will also support civil and commercial users by providing continuity of service. These Required System Characteristics for PVT systems and their descriptions are outlined in Table 1-4. Specific requirements for each Required System Characteristic may be found in Section 4 with a tabular summary of requirements in Appendix A.

Table 1-4: Required System Characteristics

CHARACTERISTIC	DESCRIPTION

Position Accuracy	• Degree of conformance of an estimated position at a given time with the true position at that time
	• Includes a statement of the uncertainty in position
	• Three types of accuracy:
	    • Predictable - accuracy of a system's position solution with respect to the charted solution.
	    • Repeatable - Accuracy with which a user can return to a position whose coordinates have been measured at a previous time with the same navigation system
	    • Relative - Accuracy with which a user can measure position relative to that of another user of the same navigation system at the same time

Velocity Accuracy	• Degree of conformance between the estimated or measured velocity of a platform at a given time and its true velocity.
Timing Accuracy	• Degree of conformance of an estimated time or time interval with the true time; for standard-based timing • Ability of the system to provide accurate common time reference relative to UTC (USNO). • Precise measurements for accurate time transfer to fixed station and mobile users (air, land, sea, and space). • Precise measurements for supporting frequency calibration and rating of local clocks for self-contained operation in the absence of time transfer information or signals • Ability of the system to provide standardized timing information interfaced to related or integrated systems for extra-system synchronization to a common reference

Integrity	• Ability of a system to provide timely warnings to users when the system should not be used
	    • Interpret signal information and determine if the signal information exceeds the specified performance criteria for that particular phase of operation and provide timely warning
	    • Navigation Signal Monitoring Capability - monitor PVT signals from the system
	    • Warning to Users - timely warning to users when specific satellites and/or the system is not available for use
	    • Monitor system signal to ensure that the number and duration of unannounced/unwarned failures which result in hazardously misleading information (HMI) are minimized

Availability	• Percentage of time that the services of the system are adequate to permit all requirements to be met including determination of position, velocity, or time to a specified level of accuracy • Indication of the ability of the system to provide usable service within the specified coverage area • Signal availability is the percentage of time that PVT signals transmitted from external sources are available for use. • Function of both the physical characteristics of the environment and technical capabilities of the transmitter facilities.
Security	• Resistance to countermeasures including: Meaconing, Interference, Jamming, and Intrusion (MIJI), physical attack, and sabotage
Continuity of Service	• Ability of a PVT system to provide required service over a specified period of time without interruption. • Expressed in terms of the probability of not losing the radiated signals.
Affordability	• Ability to meet requirements within defined budgetary constraints.
Coverage	• Surface area or space volume in which the signals are adequate to permit all requirements to be met including determination of position, velocity, or time to a specified level of accuracy • Influenced by system geometry, signal power levels, receiver sensitivity, atmospheric noise conditions, and other factors which affect signal availability
Supportability	• Degree to which all logistics elements combine to satisfy system dependability requirements • Ability to maintain control of the system • Includes manufacture, delivery, integrated training and simulation systems
Survivability	• Capability to avoid or withstand the impact of a hostile environment (man-made or natural) without suffering an abortive impairment of the ability to accomplish the most critical mission requirements
Interoperability	• Ability of PVT information to be readily used by numerous applications with applicable formats

1

SECTION 2

2. RESERVED

SECTION 3

3. SHORTCOMINGS OF EXISTING SYSTEMS

3.1 INTRODUCTION

This section addresses shortcomings in existing PVT systems and the impact on future needs. While current systems satisfy most of today's requirements, the increasingly stringent accuracy needs of users are driving the demand for more capable PVT systems. The "Information Age" has brought about the need for an unprecedented level of precision for military, civil, and commercial PVT applications. Current and projected systems cannot provide the position, velocity, and timing accuracy, nor the integrity, availability, security, continuity of service, coverage, supportability, survivability, or interoperability needed to support tomorrow's dynamic operations. Additionally, in an environment of constrained military budgets and manpower levels, new PVT systems must be economically feasible and effective. These shortcomings directly lead to the requirements presented in Section 4.

3.2 EXISTING AND PROJECTED SYSTEMS DESCRIPTION

Table 3-1 provides a summary of the characteristics of the current and projected major US military and civil PVT systems. A short description of each system is provided in the following paragraphs. Other current and projected PVT systems are addressed in Appendix E.

3.2.1 Ground Controlled Approach/Precision Approach Radar

Ground Controlled Approach (GCA) and Precision Approach Radar (PAR) are precision landing aids for military aircraft. A ground controller is provided with aircraft position relative to a fixed approach path. The operator announces aircraft location relative to the glideslope until the pilot has visual contact with the runway or until a minimum altitude is reached. No special equipment is needed on the aircraft itself. Voice instructions are passed by very high frequency (VHF) and ultra-high frequency radios. GCA and PAR are NATO standard precision landing systems and are deployable.

Table 3-1. Current and Projected Major PVT Systems Summary

System	Service	Coverage	Accuracy	Availability	Status		Operator
					DoD	**Civil**	
Ground Controlled Approach/ Precision Approach Radar	Position	18.5 km from runway threshold (deployed worldwide)	± 1.3° azimuth ± 1.1° elevation ± 60 m range		Operational		Military Services
Global Positioning System	Position, Velocity, Timing	Global and parts of Space	Horz (SEP) SPS: 100 m PPS: 16 m Timing: 100 nsec Velocity: .2 m/sec	99.85% (24 hour interval)	Operational	Rapidly increasing use, replacing most systems	US Air Force
Instrument Landing System	Position	Localizer: ± 2° from centerline, Glideslope: 3° from horizontal, Marker Beacon: ± 40°	In meters (2δ) Cat III: ± 4.1 azimuth ± 0.4 elevation	≅ 99%	Operational	Transition to WAAS and LAAS (2005 to 2010)	Military Services, FAA
Inertial Navigation Systems (many variations)	Position, Velocity	Unlimited - used on aircraft, ships, submarines, spacecraft	Aircraft: Pos: ± 1.85 km/hr Vel: ± 0.76 m/sec		Operational	Operational	Military and Civil using platforms
Long-Range Navigation (LORAN-C)	Position, Timing	CONUS, US coasts, Great Lakes, Alaska	Predictable: 460 m, Repeatable: 18 to 90 m Timing: 200 nsec (normal)	> 99%	Phased out in 1994	Phaseout by Dec 2000, transition to GPS	US Coast Guard
Microwave Landing System	Position	40 degrees from center line out to 20 nm in both directions	Cat I ± 9.1 m az ± 3.0 m el	Near 100%		Deploying 29 sets; transition to WAAS and LAAS (2005 to 2010)	FAA
Radiobeacons (Aeronautical & Maritime)	Position	CONUS	Aeronautical: ± 3° to ± 10° Maritime: ± 3°	> 99%	Operational - about 200 aeronautical	> 700 FAA aeronautical, Phaseout by 2000 at VOR sites, 4 USCG maritime	Military Services, FAA, US Coast Guard, about 800 non-Federal
Omega	Position, Timing	Worldwide continuous	Predictable/ Repeatable: 3.7 to 7.4 km Relative: 463 to 926 m	> 99%		Terminate US participation Sep 1997	System control and US stations by US Coast Guard, overseas stations by partner nations

System	Service	Coverage	Accuracy	Availability	Status		Operator
					DoD	Civil	
VHF Omnidirectional Range/Distance Measuring Equipment	Position	Line of sight, widely deployed	VOR - ± 4.5° DME - 0.5 nm	Near 100%		VOR - begin phaseout 2005 DME - phaseout 2000	FAA
Tactical Air Navigation	Position	Line of sight, widely deployed	Azimuth: ± 1° (135 Hz element, ± 4° (15 Hz element) Distance: same as DME	> 99%	Operational - 173 beacons; begin phaseout 2005	640 beacons operated for DoD	Military Services, FAA
GPS Wide Area Augmentation System	Position, Velocity, Timing	48 contiguous states, Hawaii, Puerto Rico, part of Alaska	Enroute: 100 m (95%); Cat I: 12 m vertical, 40 m horizontal (95%)	Enroute: 99.999% Cat I: 99.9%		IOC: end 1998 FOC: by 2001	FAA
GPS Local Area Augmentation System	Position, Velocity, Timing	Expected to be similar to WAAS	TBD - must meet Cat II/III precision approach	TBD		Specifications by 1998, Cat II/III capability by 2005	FAA

3.2.2 Global Positioning System

The GPS is a space-based radionavigation capability. Due to superior coverage, accuracy, availability, and survivability, it is rapidly supplanting many systems. Originally developed as a force enhancement capability for US forces, a role that will continue for the foreseeable future, GPS is proving to be of significant benefit to the civil community in an increasingly large number and variety of applications. To make the service generally available while ensuring that national security interests are protected, two services are provided. Precise positioning service provides full system accuracy to US and allied forces and other authorized users. Standard positioning service provides accurate positioning capability to civil users worldwide. Several upgrades are underway or planned for the space (Block IIR and IIF) and operational control segments and a wide variety of UE is currently available.

3.2.3 Instrument Landing System

The Instrument Landing System (ILS) provides military and civil aircraft with precision vertical and lateral navigation (guidance) information during approach and landing. Associated marker beacons or distance measuring equipment identify the final approach fix, the point where the final descent to the runway is initiated. Federal regulations require that part 121 aircraft be equipped with ILS avionics and it is also extensively used by general aviation. ILS is a standard civil landing system in the US and abroad and is protected by ICAO agreement to 1 Jan 2010.

3.2.4 Inertial Navigation Systems

Inertial Navigation Systems (INS) are self-contained systems that operate autonomously and provide reliable and accurate platform attitude, position, and velocity information regardless of weather or electronic warfare. They are capable of worldwide operation over a wide range of velocities, attitudes, and accelerations. After initialization using known position and velocity, an inertial system provides continuous estimates of position, velocity, and attitude. Key components of an INS are an inertial measurement unit, a navigation computer, and a control and display unit. Major military INS programs include the USAF Standard Navigator, Navy Carrier Aircraft INS, Aircraft Carrier Navigation Systems, Electrically Suspended Gyroscope Navigation, and the AN/WSN-5 Inertial Navigation System.

3.2.5 Long Range Navigation

The Long-Range Navigation (LORAN-C) system provides radionavigation coverage for maritime operations in US coastal areas. It provides position and precise timing services for military and civil air, land, and marine users. It is approved as a supplemental air navigation system and serves users that operate under visual flight rules. The system serves the 48 contiguous states, their coastal areas, the Great Lakes, and parts of Alaska. LORAN-C is expected to continue service until December 2000 to accommodate transition to GPS. Operations after that will depend on whether LORAN-C meets requirements that can't be satisfied by GPS or other systems. The DoD requirement for LORAN-C ended in 1994.

3.2.6 Microwave Landing System

The Microwave Landing System (MLS) does not have the siting problems of ILS and offers higher accuracy and greater flexibility, permitting precision landings at more airports. A limited procurement of Category I MLS equipment began in 1992 for installation at 29 sites. The FAA terminated the development of Category II and III MLS based on favorable GPS test results and budgetary restraints. Category II and III equipment could be purchased on the open market if a need should arise in the future. Phaseout of Category I MLS is expected to begin in 2005 and be completed by 2010. The USAF developed and is deploying 37 mobile MLS systems for contingency operations.

3.2.7 Radiobeacons

Aeronautical radiobeacons are used for transition from enroute to precision terminal approach facilities and as nonprecision approach aids at many airports. Some state and locally owned beacons are used to provide weather information to pilots. In Alaska and some remote areas, radiobeacons are also used as enroute facilities. FAA operates more than 800 beacons, the military about 200, and non-Federally operated about 800. Where equivalent VHF Omnidirectional Range facilities are available, decommissioning of FAA beacons will begin in 2000. Remaining FAA stand-alone beacons will be rapidly phased out after 2005. Maritime radiobeacons serve as backup to more sophisticated navigation systems and as a low-cost, medium accuracy system for vessels equipped with only minimal radionavigation equipment. Use has dwindled because of the availability of inexpensive LORAN-C and GPS receivers. However, the US Coast Guard (USCG) still operates four maritime beacons. Maritime beacons not modified to carry differential GPS correction signals are expected to be phased out by 2000.

3.2.8 Omega

Omega was developed and implemented by the US Navy and system control exercised by the Coast Guard. Eight stations are operated by the US and six partner nations. International civil use includes the sole means of oceanic aircraft navigation because of its worldwide coverage. Omega also provides timing service. With the achievement of full operational capability by GPS, it is anticipated that aviation users will quickly transition to GPS. The US intends to terminate its role in Omega in September 1997. The DoD no longer requires Omega, although limited use is expected while the system remains operational.

3.2.9 Very High Frequency Omnidirectional Range/Distance Measuring Equipment

Very High Frequency Omni-Range/Distance Measuring Equipment (VOR/DME) is currently the primary means of navigation in the National Airspace System (NAS). It will remain primary for enroute through non-precision approach phases of flight until GPS is proven to meet appropriate RNP levels and integrity requirements for these phases of flight and the GPS WAAS is approved as a sole means of navigation. Phase out of VOR/DME from the NAS is anticipated about 2005 with completion by 2010. DoD requirements for VOR/DME will terminate when military aircraft are properly integrated with appropriate GPS/augmentation user equipment and GPS is certified by DoD to meet RNP for national and international controlled airspace. The target date to begin phaseout of DME is 2000; for VOR the date is 2005.

3.2.10 Tactical Air Navigation

This is the military counterpart to VOR/DME. The DoD requirement for Tactical Air Navigation (TACAN) will terminate when military aircraft are properly integrated with appropriate GPS/augmentation user equipment and GPS is certified by DoD to meet RNP for national and international controlled airspace. Target date for beginning phase out of TACAN is 2005.

3.2.11 GPS Wide Area Augmentation System

The WAAS is a GPS augmentation that provides a signal-in-space to aviation users supporting enroute through Category I precision approach navigation. WAAS provides: (1) integrity data on GPS and geostationary earth orbit (GEO) satellites, (2) wide area differential corrections, and (3) an additional ranging capability. A network of wide-area reference stations and wide-area master stations receive and process GPS satellite data to determine integrity, differential corrections, residual errors, and ionospheric information for each monitored satellite. This information is sent to a ground earth station and uplinked, along with the GEO navigation message, to GEO satellites. GEO satellites downlink this data on GPS Link 1 frequency. In addition to GPS integrity, WAAS will verify its own integrity. Minimal modifications to standard GPS receivers are required in order to use WAAS.

3.2.12 GPS Local Area Augmentation System

The Local Area Augmentation System (LAAS) will provide corrections to GPS (and WAAS) for aircraft within line of sight of a ground reference station. It is expected to support Category II/III precision landing applications. It will also provide information for Category I landings at high capacity airports and certain locations where WAAS cannot provide this service. Work in this area is being closely coordinated with development of local and differential GPS systems for special category I precision approaches being funded by private industry. Funding and spectral placement of LAAS are issues that must be resolved, but the FAA expects that LAAS Category II/III will be available for public use by 2005.

3.3 LIMITATIONS OF CURRENT SYSTEMS

The USG operates radionavigation systems as one of the necessary elements to enable safe transportation and encourage commerce within the United States. It is a goal of the USG to provide this service in a cost-effective manner. In order to meet both civil and military radionavigation needs, the Government has established a series of radionavigation systems over a period of years. Each system utilizes the latest technology available at the time of introduction to meet existing or unfulfilled needs. Policies and plans for federally provided radionavigation services are delineated in the FRP. The FRP describes areas of authority and responsibility and provides a management structure by which the individual USG operating agencies can define and meet radionavigation requirements in a cost-effective manner. It is the official source of radionavigation policy and planning for the USG. The existence of privately operated radionavigation systems may also be a factor in USG planning.

Current and projected PVT systems cannot meet future needs due to aging equipment, much of which is labor and training intensive, and anticipated higher accuracy needs. Current military systems do not meet projected military requirements during conflicts in which an enemy may attempt disrupt their usage. Also, providing extremely accurate PVT signals to the general public, including foreign countries, could result in adversaries using the service against the US.

While the survivability of any radionavigation system is scenario-dependent, in almost any scenario the GPS is expected to be more survivable than other systems because: (1) moving transmitters in space are less vulnerable than ground-based transmitters; (2) spread spectrum transmission techniques protect against jamming; (3) anti-spoofing is available; and (4) transmitters are hardened against EMP.

In addition to the major systems discussed above, there are numerous other specialized PVT systems in use or projected. These systems are addressed in Appendix E.

Current and projected major and other, mostly special purpose, PVT systems and their capability to meet future requirements are depicted in Table 3-2. For each system, a red (R), yellow (Y), or green (G) indicator is used to portray the degree to which the PVT system is able to meet future requirements for each required system characteristic. Definitions of indicators and rationale for the indicators assigned to each system are provided in Appendix F. Several foreign systems were described in Section 1. While US military forces may use some of these systems in non-hostile conditions, US Forces must not be dependent on PVT assets of other nations. Only US PVT systems were rated and systems with planned phaseout dates were not rated.

Table 3-2. Current and Projected PVT Systems' Capabilities to Meet Future Requirements

	REQUIRED SYSTEM CHARACTERISTICS											
MAJOR SYSTEMS	**POSITION ACCY**	**VELOCITY ACCY**	**INTEGRITY**	**AVAILA-BILITY**	**TIMING ACCY**	**COVER-AGE**	**SUPPOR-TABILITY**	**SECUR-ITY**	**INTEROP/ STANDRD**	**CONTINU-ITY SVC**	**SURVIVA-BILITY**	**AFFORD-ABILITY**
GCA/PAR	G	Y	Y	G	R	Y	G	Y	Y	Y	Y	Y
GPS	Y	Y	R	Y	G	Y	G	Y	G	G	G	Y
ILS	Y	R	Y	G	R	Y	Y	Y	Y	Y	Y	G
INS	Y	Y	G	G	R	G	G	G	G	G	G	G
Maritime DGPS	G	G	G	Y	G	Y	G	Y	Y	G	Y	Y
GPS WAAS	G	G	G	Y	G	Y	G	Y	G	Y	Y	Y
GPS LAAS	G	G	G	Y	G	Y	G	Y	G	Y	Y	Y
OTHER SYSTEMS												
ATC Radar Beacon Sys	Y	Y	Y	G	R	Y	G	Y	Y	G	Y	G
ATC Radar	Y	Y	Y	Y	R	Y	G	Y	Y	G	Y	Y
Bottom Contour Nav	Y	Y	G	Y	R	Y	G	G	Y	G	G	G
Carrier Systems for Controlled Approach of Naval Aircraft	Y	R	G	G	R	Y	G	Y	Y	Y	Y	G
Celestial Nav	Y	Y	G	Y	R	G	G	G	G	G	G	G
Differential GPS (military)	G	G	Y	Y	G	G	G	Y	Y	G	Y	Y
Digital Airport Surveillance Radar	Y	Y	G	G	R	Y	Y	Y	Y	G	G	G
Direction Finding	Y	Y	G	G	R	Y	G	Y	G	G	Y	G

	REQUIRED SYSTEM CHARACTERISTICS											
MAJOR SYSTEMS	**POSITION ACCY**	**VELOCITY ACCY**	**INTEGRITY**	**AVAILA-BILITY**	**TIMING ACCY**	**COVER-AGE**	**SUPPOR-TABILITY**	**SECUR-ITY**	**INTEROP/ STANDRD**	**CONTINU-ITY SVC**	**SURVIVA-BILITY**	**AFFORD-ABILITY**
Doppler	Y	Y	Y	G	R	Y	G	Y	Y	G	G	G
Digital Scene Matching Area Correlation	G	G	G	Y	R	Y	Y	G	Y	G	G	G
Joint Tactical Information Dist System	Y	Y	Y	Y	R	Y	G	G	Y	G	G	G
Marine ATC & Landing Systems	G	R	G	G	R	Y	Y	Y	Y	G	Y	Y
Survey Instrument Az, Gyro (lt wt)	Y	R	Y	G	R	Y	G	G	Y	G	G	G
Stabilization Reference Package/Pos Det System	Y	R	Y	G	R	G	G	G	Y	G	G	G
Terrain Contour matching	G	G	G	Y	R	Y	Y	G	Y	G	G	G
Vessel Traffic Services	Y	Y	Y	Y	R	Y	G	Y	Y	G	Y	G

DRAFT

3.4 POSITION ACCURACY

3.4.1 Shortcomings

3.4.1.1 Timeliness. Current systems and methods will not provide direct, real-time PVT information to the degree of accuracy within the time constraints required to support all users of fielded or emerging military systems.

3.4.1.2 Civil Air Navigation. Current PVT systems and UE cannot meet future civil air navigation accuracy requirements for the approach and landing phase. Further, current systems cannot meet civil marine or space navigation accuracy requirements.

3.4.1.3 Seismic Surveys. To get one meter accuracy for the positioning of shot holes and geophone locations, users must transport extra equipment in order to set up a base station - GPS receiver, modem, radios, extra batteries, solar panels.

3.4.1.4 Geodetic Surveys. Users have no means of computing geodetic quality positions in the field to check on results on the spot.

3.4.1.5 Cable Mapping. To properly map fiber cable, it is necessary to locate it properly with respect to lease boundaries, railroad tracks, roads, sidewalks, or other utilities. GPS, with augmentation, is not affordable.

3.4.1.6 Property Surveys. GPS position accuracy is inadequate, particularly in elevation.

3.4.1.7 Marine Navigation. For some vessels, accuracy is not sufficient to calculate if the anchor is dragging or if the vessel is about to enter a tight channel in fog. The lack of horizontal accuracy, when using stand-alone GPS receivers dictates the use of differential GPS (DGPS) systems for harbor and approach bathymetric surveys

3.4.1.8 Land Management. Some land management applications require extraordinary accuracy. With the current limits on accuracy, post processing is required for many applications. Post processing is time consuming and expensive. Base stations must be set up and maintained; person-hours spent post-processing GPS data nationwide within the Bureau of Land Management is immense. Real-time corrector broadcasting is unreliable in rough terrain and canopy, and is also expensive.

3.4.2 Impact

3.4.2.1 Civil Air Navigation. Insufficient position accuracy will impact safety of flight and shipping in military and civil sectors. In military applications, it would adversely affect the accurate delivery of weapons on their intended targets.

Without improved capabilities, existing systems must continue to be maintained and reliance will continue to be placed on human observation for rail and automobile navigation, as well as other potential uses of PVT capabilities. Failure to provide required position accuracy will result in inefficiencies and potential loss of profitability.

3.4.2.2 Seismic Surveys. Transporting equipment imposes an extra logistical burden, sometimes at the end of long supply lines. The need for a base station crew requires users to return to their starting point in order to recover the equipment, adding further to fuel loads.

3.4.2.3 Geodetic Surveys. Users currently have to build redundancy into survey field programs to make sure they get the right amount of quality data. It takes two years to arrange an experiment in the more remote part of Antarctica, so returning to correct data acquisition mistakes is not practical.

3.4.2.4 Cable Mapping. While the cost of GPS receivers to support fiber optic cable mapping may have been acceptable, the manpower and additional equipment costs associated with setting up differential base stations was not affordable. Commercially available differential broadcasts do not cover most of the US, while fiber optic cable covers the US. With these unresolvable equipment and manpower costs, GPS was rejected for use in mass fiber optic cable route surveying.

3.4.2.5 Marine Navigation. Current accuracy of the basic GPS signal requires that certain Naval applications deploy and utilize differential GPS. This creates a burden on the operating forces. The USCG maritime DGPS system is expected to provide position accuracy better than 10 meters (2 drms) for US harbor and harbor approach areas. Until DGPS service is declared fully operational by the USCG, signal availability and accuracy are subject to change due to testing of this developing service and the uncertain reliability of prototype equipment.

3.5 VELOCITY ACCURACY

3.5.1 Shortcomings

Current PVT systems do not provide the required velocity accuracies for some precision guided munitions and heavy artillery users. Due to the high rate of speed at which these weapons travel, extremely precise velocities must be provided to precisely compute present positions, anticipate upcoming navigational vector changes, avoid terrain when flying in mountainous or hilly environments, as well as assist integration of external PVT information with internal capabilities. As fire-and-forget weapon technology improves and matures, and the quantity of users employing this technology rises, reliance upon more highly accurate velocity information will likewise increase.

3.5.2 Impact

Dichotomies between external and internal systems could result in navigational errors. Even the smallest difference between expected position and actual position may result in turns being missed, terrain being struck, or a target missed resulting in overall mission failure.

3.6 TIMING ACCURACY

3.6.1 Shortcomings

Current PVT systems do not provide a readily obtainable, highly accurate time to all users, without the use of additional equipment or equipment modifications. Further, the impending phaseout of LORAN-C and Omega systems will reduce timing service backup capability resulting in greater reliance on GPS.

3.6.2 Impact

Some command and control communications systems will not operate properly without sufficient timing accuracy. Many modern systems require accurate time signals. Timing anomalies can adversely impact the proper functions of dependent systems. Lack of timing accuracy limits the capability of secure communications and intelligence. The GPS system would not be able to provide the required level of timing accuracy without the support of LORAN and OMEGA. Accurate position and velocity determination would also be degraded.

3.7 INTEGRITY

3.7.1 Shortcomings

The basic GPS must be augmented to meet current military and civil aviation and marine integrity requirements. Receiver autonomous integrity monitoring (RAIM), a receiver software program, and DGPS are two methods of satisfying integrity requirements.

With the current design of the monitor segment of GPS, a satellite may transmit an unhealthy signal for two to six hours before it can be detected and corrected. Current PVT systems are unable to monitor all signals at all times. Currently, a non-standard code is transmitted by GPS satellites when an out-of-tolerance PVT signal is detected. The integrity monitoring system is inadequate to detect/report signal-in-space errors or problems that do not automatically trigger the transmission of the non-standard code. Therefore, integrity warning is not available continuously. Furthermore, it is not possible to meet future monitoring requirements to detect the transmission of hazardously misleading information (HMI).

For marine applications, there is no indication when the current PVT system is not operating correctly.

3.7.2 Impact

As the number of PVT users increases, there is a greater need to increase monitoring to detect abnormal transmissions. Without integrity warning, safety of flight and shipping in both military and civil sectors will be adversely affected. Aircraft and other systems have no ability to determine whether navigation systems are working properly and, therefore, no way to tell whether on-board equipment is giving true information. Many communications systems, both military and civil, depend on GPS for timing. Integrity monitoring is critical to continuous operation of those communications links. Adequate GPS integrity is only available with RAIM or DGPS.

3.8 AVAILABILITY

3.8.1 Shortcomings

There is an ever growing dependence on time-sensitive PVT systems. Currently, PVT systems do not provide a usable signal to all users at the precise time needed on an uninterrupted basis. Current systems do not meet availability needs.

Current systems cannot meet future service availability requirements. Current methods and procedures for constellation sustainment could adversely affect availability if a satellite suddenly fails and there is none immediately available to replace it.

The availability of the current PVT systems, especially the GPS constellation, does not meet all user requirements (e.g., 100 percent is specified for railroad collision avoidance).

3.8.2 Impact

The growth of dependence on PVT systems, particularly GPS, emphasizes the critical nature of operations and such issues as safety of life. As more people and systems come to rely on PVT systems for day-to-day operations, there is a greater likelihood that a catastrophic event will occur should critical systems fail to operate or provide the necessary level of accuracy.

3.9 SECURITY

3.9.1 Shortcomings

3.9.1.1 Selective Availability. Much of the military advantage of SA is questionable as SA has been substantially bypassed by civil and commercial augmentation systems. Even though the PDD declares national security as the top priority, the PDD stated the intention to discontinue SA by 2006. The continued use of SA is contrary to the civil goals of improved performance.

3.9.1.2 Electronic Warfare. Multiple assessments of the GPS between 1993 and 1997 have all pointed out GPS electronic warfare shortcomings. There are weaknesses in two areas.

3.9.1.2.1 Antijam. The GPS AJ capabilities have repeatedly been identified as being inadequate. GPS performance can be severely degraded or provide erroneous information in high noise (noise jamming, multipath, spoofing, etc.) or scintillation environments.

3.9.1.2.2 Signal Fratricide. The US anticipates attempted use of the GPS civil frequency as an aid to navigation by hostile forces. US forces use the civil frequency to acquire and lock-on to other signals. The US has no capability to deny adversaries the use of GPS without impacting its own use of the system. Countering this threat would force the US to jam its own system (signal fratricide) in the area of conflict and virtually deny friendly use of GPS.

3.9.1.3 Differential GPS. The most accurate PVT system currently available is DGPS. There is a risk to using DGPS or ground-based pseudolites during conflict due to the need for stationary (and hence vulnerable) reference stations or networks.

3.9.1.4 Information Warfare. Information Warfare is a relatively new threat and there are few safeguards in place to ensure the effective detection, assessment, and response to an IW attack. Neither military nor civil systems are sufficiently protected against unauthorized monitoring and intrusion.

3.9.1.5 Other Shortcomings. Positive train separation (a railroad anti-collision safety system) requires highly reliable, precision positioning information. During testing in the Portland, Oregon area, users experienced loss of GPS signal due to close proximity of non-railroad RF emitters. Loss of signal was experienced in locations where there were no known or observed obstructions to the signal path between the satellite and receiving antenna.

3.9.2 Impact

Adversarial jamming of the GPS signal would lead to loss of use by US forces and all other users in the affected area. Adversaries also may attempt to exploit GPS/DGPS. The lack of appropriate countermeasures to adversarial use would force the US to jam its own signals, again leading to loss of use by the US and all other users in the area.

For the military and intelligence communities, information is rapidly becoming a critical element of modern warfare and information dominance will be a key goal in future conflicts. This will make US information systems prime targets for enemy attacks. As information becomes a center of gravity, it must receive the protection needed to ensure proper security and uninterrupted availability to the user. Information warfare could also lead to loss of use of PVT systems due to adversarial action.

Loss of PVT signal for collision avoidance due to RF interference could result in severe consequences in many military and civil applications.

3.10 CONTINUITY OF SERVICE

3.10.1 Shortcomings

Continuity of service is a subset of system availability. The current GPS system does not meet availability requirements (e.g., Cat I approach and Landings). Therefore, users are concerned the system will not meet continuity requirements and will not certify GPS as a sole means.

3.10.2 Impact

The loss of service at critical times of aircraft precision approach could have severe consequences, including loss of life.

3.11 COVERAGE

3.11.1 Shortcomings

Current PVT signals do not provide consistent, equally available coverage worldwide. Though GPS provides worldwide coverage, under certain conditions the signal is not available in steep urban valleys, steep natural valleys, under dense foliage, inside buildings, underground, underwater, and in space above the orbit of GPS satellites.

For a three-dimensional position fix, a receiver must have at least five GPS satellites in view or utilize aiding (height, time) in order to provide RAIM. A minimum of five independent position measurements is required to support identifying an out of tolerance signal while a minimum of six independent position measurements is required to identify and isolate an out of tolerance signal from a single satellite. This condition is not always satisfied with the existing constellation, resulting in "[1]RAIM holes" and limiting GPS use as a supplemental navigation system.

There are too few space vehicles (SVs) available 24 hours a day to support real-time kinematic (RTK) surveying. Current signals cannot provide service when users are inside buildings or are under significant forest canopy. RTK carrier phase techniques with "on the fly" integer ambiguity resolution algorithms require at least 5 satellites with at least 15 degrees elevation. At high latitudes (above 60 degrees), there are daily periods when this is not possible to achieve.

Many land navigation applications can not effectively utilize GPS due to the shadowing problem. This is especially true for applications based on carrier phase observations.

Assurance of uninterrupted civil access to the GPS signal, for domestic and international civil sectors, is of paramount importance. As emergency services and critical navigation services become more reliant on GPS, an interruption of service will become less tolerable. GPS coverage can sometimes be less than optimal due to temporary removal of satellites from service.

[1] RAIM hole is defined to be any time that at least five GPS satellites are not in view above a mask angle of 7.5 degrees.

Some nations perceive a lack of detailed GPS information being provided for certification of GPS within those nations.

3.11.2 Impact

Lack of consistent coverage can impact all users, limiting safety, access to service, and accuracy. In operations conducted in rural or urban canyons, as canyon walls become steeper and taller, access to PVT signals are limited and accuracy decreases.

RTK surveying needs at least 5 SVs. Currently, there are periods when only 5 SVs are available, so any blockage from trees, buildings, etc, would preclude RTK operations. Surveyors operating among trees and buildings experience poor GPS and augmentation signal penetration.

Many potential applications, such as guidance systems for the blind, cannot tolerate any interruption of positional data and are, therefore, not supportable with current systems.

This issue is of extreme importance to non-domestic civil users and may preclude their acceptance of any US provided position/navigation (pos/nav) system for critical services. An example is a non-domestic civil defense agency whose responsibility is the evacuation of citizenry during emergencies. If their city/country might be in a theater of conflict, use of GPS as their primary posnav system can not be considered. Obviously, this would also be of concern to domestic civil defense agencies since they would be forced to rely on units (such as the National Guard) that possess equipment capable of receiving PPS.

Certification of GPS is sometimes denied by nations that perceive insufficient information being provided.

3.12 SUPPORTABILITY

3.12.1 Shortcomings

The GPS Operational Control Segment is unable to operate all GPS satellites 100 per cent of the time. Visibility gaps exist because of ground control site locations. However, the addition of National Imagery and Mapping Agency (NIMA) ground stations to the control segment will mitigate this shortcoming.

In order to provide timely assistance to a GPS satellite, the Operational Control Segment requires a dedicated network of Ground Antennas and Monitor Stations providing worldwide monitoring and command and control capabilities. Due to the increased demand on system reliability and availability, the current network will not be able to support future PVT requirements.

Some current systems require extensive training of operators and/or support personnel. Current ground-based radionavigation systems require training for operations, spare parts to maintain operations, and facilities for operations. Budgetary constraints limit the amount of on-hand spares, making it difficult to perform required maintenance, both corrective and preventive.

3.12.2 Impact

Impacts include a lack of service, extra costs, degraded system accuracy, and reduced availability.

3.13 SURVIVABILITY

3.13.1 Shortcomings

The primary threats to current PVT systems are described in Section 2. The ground control and space segments of current space-based PVT systems are not survivable.

3.13.2 Impact

Denial of PVT information would adversely affect terrestrial forces, reducing their effectiveness and slowing operating tempo. The use of these systems will assist in fostering an integrated terrestrial force that can apply combat power at desired times and places. Loss of that capability would affect the effectiveness of these forces.

3.14 INTEROPERABILITY

3.14.1 Shortcomings

Military and civil users operate with a wide variety of PVT systems and equipment. Some of these systems are not interoperable. Although GPS is now widely used, many military platforms are not yet equipped with GPS receivers.

3.14.2 Impact

Failure to incorporate interoperability in future PVT systems will result in proliferation of dissimilar systems and equipment, as well as extra costs. Not all users could take advantage of significant technological improvements and, therefore, service and accuracy improvements.

SECTION 4

4. REQUIRED CHARACTERISTICS

4.1 INTRODUCTION

Requirements for DoD and civil PVT capabilities are described in this section in terms of a common set of interrelated required system characteristics that apply in varying degrees to different classes of users and missions. These characteristics include: **Position Accuracy, Velocity Accuracy**, **Timing Accuracy, Integrity, Availability, Security, Continuity of Service, Coverage, Supportability, Survivability, Interoperability,** and **Affordability.** The inter-relationships between these characteristics are pointed out in the characteristic descriptions.

4.1.1 Required System Characteristics

This section describes the overarching characteristics required to ensure PVT systems support military and civil needs well into the 21st Century. A required system characteristic is defined as an overarching performance or design feature needed to successfully accomplish PVT missions or tasks. These characteristics encompass primary design, cost, and risk drivers; and, therefore, need early identification in the development process. Recommendations for identification of Key Performance Parameters (KPPs) are provided after the required system characteristics are explained.

The required system characteristics identified in this section are for the "system of systems" that will collectively satisfy the system characteristics articulated here. When individual ORDs are developed and specific key performance parameters stated, additional required system characteristics may be added, and some of those identified here may be modified or combined to better describe specific system requirements.

4.1.2 Unconstrained Requirements

The requirements detailed here are unconstrained in that they are generally independent of architectural or system solutions. They are to be further refined in terms of specific architectural capabilities, costs, and risks as part of the architecture development process and the CRD/JROC approval process. Furthermore, it is anticipated that multiple material solutions will be required to satisfy various levels of requirements.

4.1.3 Parameters

Previous discussions of requirements have used average values which allow for some high errors at various times and locations. The maximum error the user can tolerate anytime and anywhere needs to be defined to provide the fidelity to minimize error levels throughout the system. Also, there have been diverse measures for the characteristics which leads to confusion about what the requirement is. In a future version, this document will use one measure for the requirements which will be stated at the 2 sigma level (95%) where appropriate.

4.1.4 Phases of Navigation

Some PVT requirements are common to both civil and military users. Both categories of users must perform the same tasks to navigate on land, within US airspace, and on waterways. For common tasks, civil and military requirements are defined in terms of discrete "phases of navigation." These phases are identified primarily by the characteristics of the navigational problem as the mobile craft passes through different regions in its voyage. For example, the aircraft navigational problem becomes progressively more complex and risky as an aircraft leaves the enroute environment, approaches an airport, and finally lands.

4.1.5 Military Requirements

Operators of military aircraft and sea vessels must meet federal and international standards when operating in common use areas. Therefore, civil navigation requirements also apply to military PVT systems. There are specific military requirements, however, that depend upon mission. The CJCS MNP provides specific DoD requirements for navigation, positioning, and timing accuracy organized by primary missions and functions with specifically related accuracy requirements.

Unique military missions and national security needs may occasionally impose a different set of requirements. Often, military requirements are of a continuous nature, i.e., PVT services must equal or exceed tactical or strategic mission needs at all times in relevant geographic areas, irrespective of hostile enemy action.

4.1.6 Multiple Characteristics

There are several requirements that involve more than one of the required characteristics. New systems must improve PVT accuracy for all civilian users. These new systems must also improve PVT accuracy, integrity, and availability to meet Category I requirements and to replace TACAN sites. The new systems must improve PVT accuracy, integrity, and availability for Category II and III landings. Further, new systems must improve PVT accuracy and integrity to meet standards to qualify as primary and sole means of navigation. Finally, new systems must improve PVT accuracy, integrity, availability, and protection for military users in high threat AORs for Category III landings.

4.1.6.1 Civil Requirements. Numerous civil requirements have been identified. The PVT system shall, as a minimum, support the following goals:

1) Reduced complexity in future PVT augmentation systems due to reduction in the number of ground stations required.

2) Cost savings from eventual elimination of many local area differential systems in conjunction with technical improvements to PVT system broadcasts.

3) Lower costs in civil space operations due to enhanced attitude determination systems and improved spacecraft tracking.

4) Improvements in atmospheric water vapor content measurements for meteorological purposes.

5) Lower costs in surface applications.

4.1.6.2 Common Use Elements. Common use elements of PVT systems must be capable of providing operationally acceptable information simultaneously and instantaneously to an unlimited number of users. The PVT system should ensure, on an uninterrupted basis, highly accurate data is provided to the broad range of user applications.

4.1.6.3 Tailorable Features. There are two other overall requirements. First, not all requirements will apply equally to all users or applications. Not all users will have a need for the maximum accuracy, integrity, availability, security, etc. the new PVT systems will provide, especially if these features are not affordable. The features must be "tailorable" for each user. Accessing one feature must not also require acquiring another feature. While tailorability may be largely a function of user equipment, it could also be related to signal structure.

The second overall requirement is closely related to the first. New PVT systems must provide a signal structure that will allow continued use of existing user equipment. However, this "backward compatibility" must not override opportunities to take advantage of new technologies. A period of dual operations may be necessary. As an example, black and white television sets can still work with color television signals (backward compatibility), but no current television receivers will work with high-definition television signals (dual operations will be necessary).

4.1.7 Organization

The following sections present the required system characteristics. In each section, the characteristics are first defined, then the most stringent quantitative requirements for each characteristic are summarized in tabular format, broken down by threshold and objective. Following these tables, the non-numerical requirements that apply to each required system characteristic are stated. A complete list of numerical requirements for each required system characteristic is provided in Appendix A. Finally, the rationale for the identification of the requirements is presented for each of the characteristics.

4.2 POSITION ACCURACY

4.2.1 Definition

4.2.1.1 Position Accuracy. Position accuracy is defined as the degree of conformance between the estimated or measured position of a platform at a given time and its true position, specified in three dimensions. Positioning provides information on the user's location relative to a specific geospatial reference coordinate system. PVT system accuracy is usually presented as a statistical measure of system error and is specified as predictable, repeatable, and relative.

Predictable accuracy: The accuracy of a radionavigation system's position solution with respect to the charted solution. Both the position solution and the chart must be based upon the same geodetic datum.

Repeatable accuracy: The accuracy with which a user can return to a position whose coordinates have been measured at a previous time with the same navigation system.

Relative accuracy: The accuracy with which a user can measure position relative to that of another user of the same navigation system at the same time.

4.2.1.2 Fix Rate. Fix rate is defined as the number of independent position fixes or data points available from a system per unit of time.

4.2.1.3 Fix Dimension. This characteristic defines whether a navigation system provides a one-dimensional line of position or a two- or three-dimensional position fix. The ability of a system to derive the fourth dimension (time) from the navigation signals is also included[2].

4.2.1.4 Timeliness. Timeliness is the amount of time needed by the user to obtain the required accuracy. This value is either obtained at the actual time of signal reception or is obtained via post-processing the received signal.

4.2.2 Requirements

In this and the following sections, the most stringent threshold and objective requirements are presented for each required system characteristic. A threshold value is a minimum acceptable operational value below which the utility of the system becomes questionable. An objective value is an operationally significant increment above the threshold. An objective value may be the same as the threshold when an operationally significant increment above the threshold is not significant or useful.

The most stringent threshold values of the requirements for the subsurface, surface, air, and space mediums are in Table 4-1. Military requirements are shown in **bold**. A complete listing of the

[2] Federal Radionavigation Plan, 1994

quantitative requirements, both military and civil, for position accuracy are in Appendix A. The source references are listed in Appendix D.

Table 4-1. Threshold Requirements for Position Accuracy

			Source
Subsurface		0.1 m	Ref 44
Surface		**0.3 m** 1 mm	**Ref 39** Ref 44
Air		**0.2 m** 0.8 m	**Ref 4** FAA
Space (NRT) (Pos/Attitude)	GEO + LEO	**25m/0.1 deg** 6m/0.1 deg	**SATOPS ADT**
Space (PP)	LEO GEO	**1cm/0.001 deg within 72 hrs** TBD	**SATOPS ADT**

Table 4-2 provides the most stringent objective values for the requirements of each of the different mediums.

Table 4-2. Objective Requirements for Position Accuracy

			Source
Subsurface		1 cm	Ref 44
Surface		**0.3 m** 1 mm	**Ref 39** Ref 44
Air		**0.1 m** 0.8 m	**Ref 4** FAA
Space (NRT) (Pos/Attitude)	GEO + LEO	**10m/0.01 deg** 20cm/0.01 deg	**SATOPS ADT**
Space (PP)	LEO GEO	**1cm/0.001 deg within 1 hour** TBD	**SATOPS ADT**

4.2.2.1 Air Navigation Requirements. The following are basic requirements for the aviation navigation systems. "Navigation system" means all of the elements necessary to provide navigation services to each phase of flight. Figure 4-1 illustrates the requirements for air navigation. The navigation system must permit the establishment and the servicing of any practical defined system of routes for the appropriate phases of flight. New accuracy requirements will become effective with the implementation of RNP. As navigation tolerances become more precise, aircraft separation requirements will decrease and more aircraft will fly closer together in a given airspace. This drives the requirement for a more frequent, accurate, and automated aircraft information reporting system. RNP will require an aircraft to be within a specific number of nautical miles of its cleared position (cross track and along track 95 per cent of the time). In conjunction with other flight instruments, the navigation system must in all circumstances provide information to the pilot and aircraft systems for performance of the following functions:

- Continuous track deviation guidance.
- Continuous determination of distance along track.
- Continuous determination of position of aircraft.
- Position reporting.
- Manual or automatic flight.

Altimetry requirements for vertical separation of 1,000 feet, below Flight Level (FL) 290, are not expected to change. Increased altimetry accuracy is needed at and above FL 290 to permit separation less than the current standard of 2,000 feet. The required future 3 sigma (99%) value of the aircraft altimetry system error has not been specified, but it must be accurate enough to support the introduction of 1,000-foot vertical separation at all flight levels.

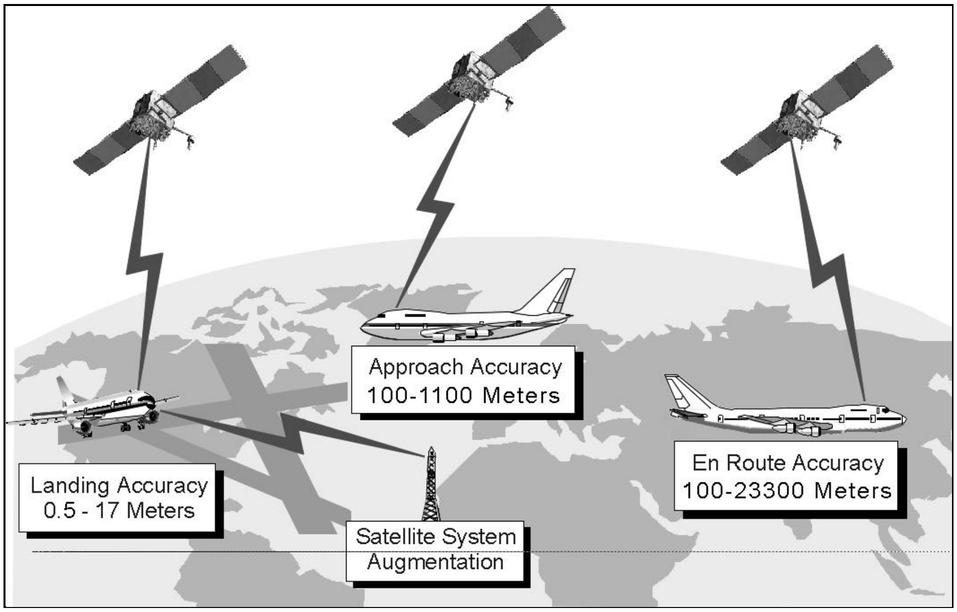

Figure 4-1. Air Navigation Requirements

Appendix A provides the position accuracy numerical requirements for aircraft in the enroute/terminal phase and in the approach and landing phase of flight. These requirements, taken in total, also tacitly address collision avoidance.

4.2.2.2 Marine Navigation Requirements. Marine navigation requirements are illustrated in Figure 4-2. Appendix A provides position accuracy numerical requirements for watercraft on inland waterways, harbor and harbor approach areas, coastal areas, and open oceans. Again, these requirements essentially address collision avoidance. Additional collision avoidance requirements, to include icebergs, may be identified in future revisions.

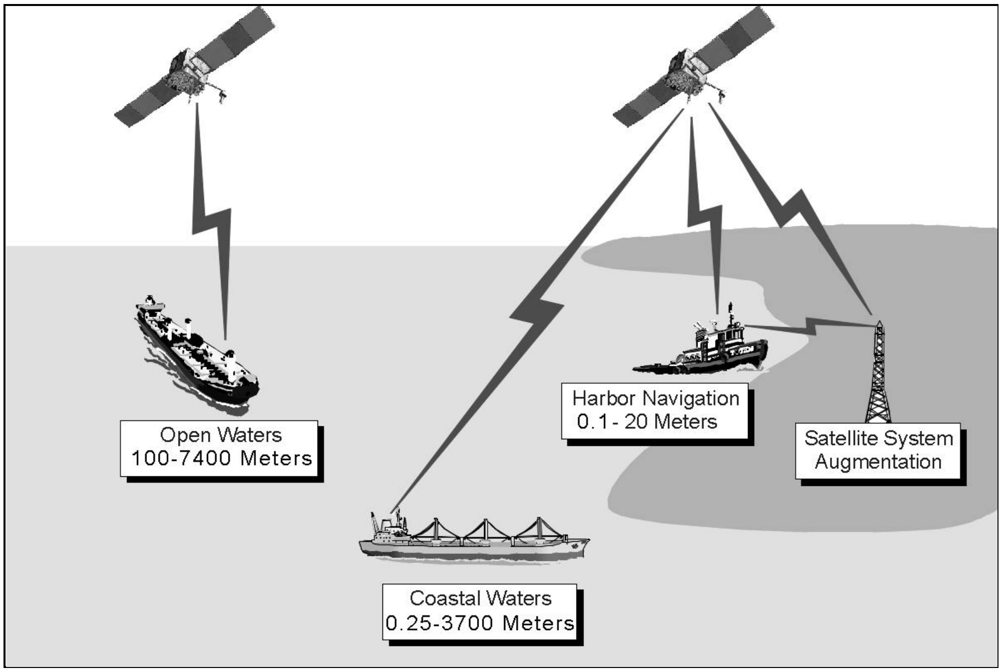

Figure 4-2. Marine Navigation Requirements

4.2.2.3 Land Navigation Requirements. Land navigation requirements are illustrated in Figure 4-3. Specific position accuracy numerical requirements for land applications are provided in appendix A.

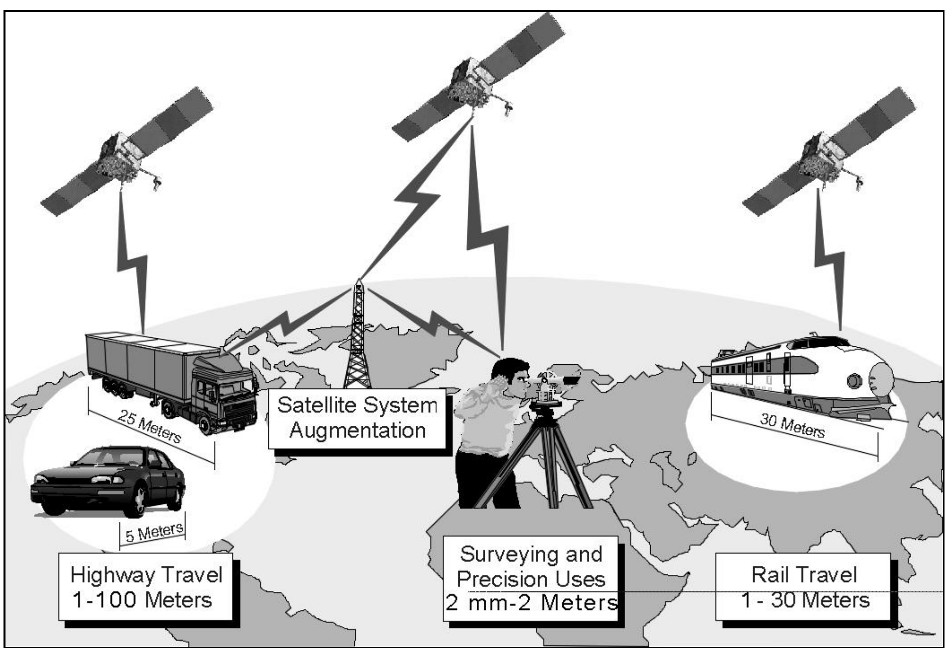

Figure 4-3. Land Navigation Requirements

4.2.2.4 Space Navigation Requirements. Space navigation requirements are illustrated in Figure 4-4. PVT services for space applications are applied in two different processing environments:

a. Near Real Time. Onboard spacecraft vehicle navigation support in near real-time applications for position and attitude determination that are used in the vehicle command and control system.

b. Post Processing. Scientific data analysis support where PVT services will be used to accurately locate instrument position in space. This type of application generally requires extreme accuracy in positioning, but in a post processing environment where raw PVT information is recorded along with instrument observation data aboard the spacecraft for later processing in a ground facility. This kind of application typically uses additional information about the PVT system developed in a ground monitoring environment that provides historical information precisely locating PVT system information sources. The post process operation then processes this historical information with the recorded observation information to derive a very precise position of the instrument.

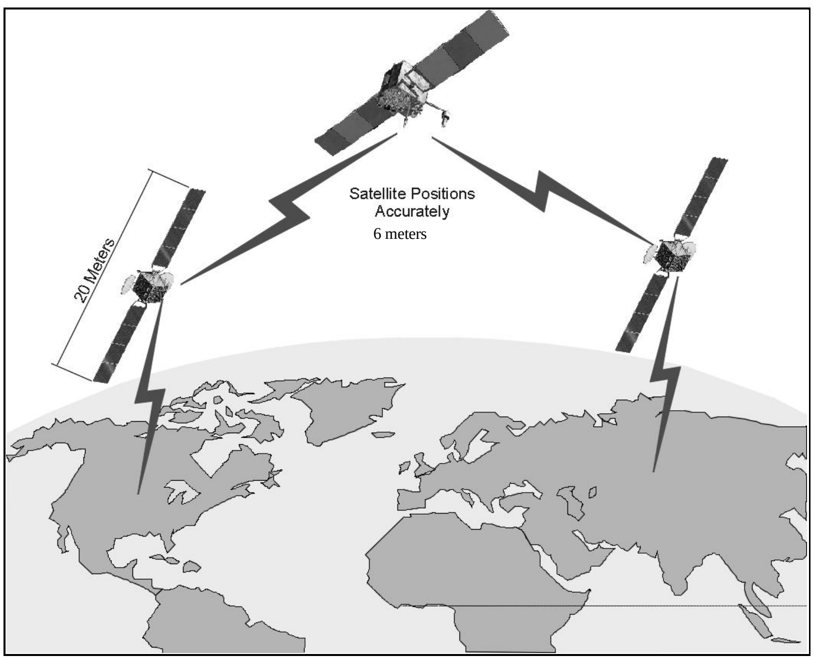

Figure 4-4. Space Navigation Requirements

4.2.2.4.1 Satellite Operations. The PVT system shall support navigation requirements of earth orbiting satellite vehicles and their payloads in both real-time and in post processing modes of operation:

a. Real-time Requirement:
Support accurate positioning, attitude determination, and precise coordinated time indication for the purpose of autonomous onboard navigation of satellite vehicles, independent of earth-based tracking systems, and during periods of both steady state orbit dynamics as well as during satellite maneuver operations.

Threshold Requirement: The PVT system shall provide real-time information to orbiting spacecraft that will enable on-orbit position location to within 25 m (3 sigma) per axis for satellites in geosynchronous earth orbit and decreasing to 6 m (3 sigma) per axis for satellites in low earth orbit. The PVT system shall support satellite attitude determination in real-time to an accuracy of 0.1 degree (3 sigma) for each spacecraft axis.

Objective Requirement: The PVT system shall provide real-time information to orbiting spacecraft that will enable on-orbit position location to within 10 m (3 sigma) per axis for satellites in geosynchronous earth orbit and decreasing to 20cm (3 sigma) per axis for satellites in low earth orbit. The PVT system shall support satellite attitude determination in real-time to an accuracy of 0.01 degree (3 sigma) for each spacecraft axis.

b. Post Processing Requirement:
Support precise positioning of satellite payload instruments through the processing of data observed and recorded onboard the satellite.

Objective Requirement: The PVT system shall supply the necessary data products for post processing of the recorded data that will enable instruments to be located to an accuracy of 1 cm (3 sigma) in each axis within 72 hrs of data recording.

Threshold Requirement: The PVT system shall supply the necessary data products for post processing of the recorded data that will enable instruments to be located to an accuracy of less than 1 cm (3 sigma) in each axis within 1 hr of data recording.

Note: Consideration should also be given to Metric Tracking Upgrade requirements for launch vehicles.

4.2.2.5 Military Navigation Requirements. Military navigation requirements are illustrated in Figure 4-5. Future PVT systems must be capable of providing the signals to meet the requirements for JPALS, Global Air Traffic Management (GATM), and other new systems as they become operational.

An ideal military positioning/navigation capability should be totally self-contained so that military platforms are capable of performing all missions without reliance on information from outside sources. The nature of military operations requires that essential navigation services be available, with the highest possible confidence that these services will equal or exceed performance requirements. This, among other considerations, necessitates a variety of navigational techniques and redundant installations on weapon system platforms.

While reliance on a single PVT system is unwise, redundant or backup systems for military operations should not be more vulnerable, less-capable external systems. Rather, they must be reliable, accurate, self-contained systems uniquely tailored to match platform mission requirements.

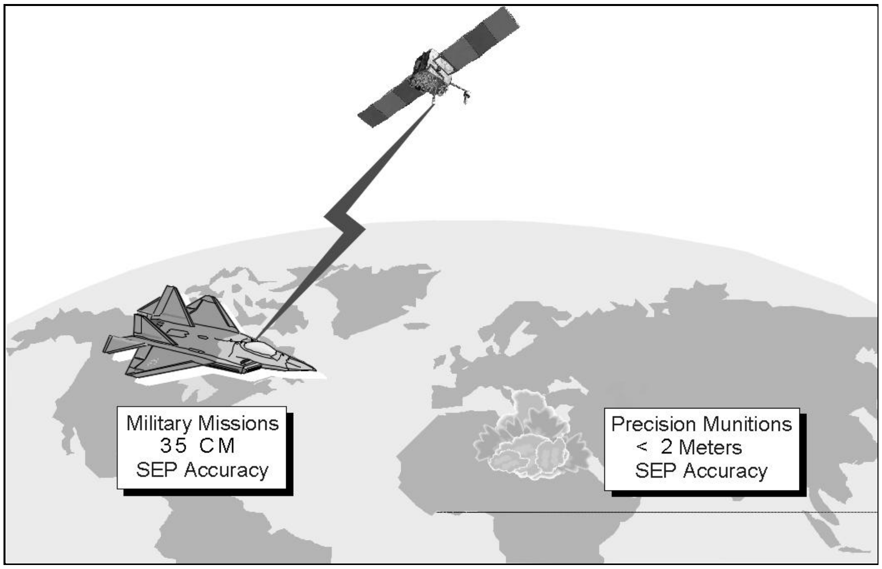

Figure 4-5. Military Navigation Requirements

4.2.2.6 Precision Munitions. Improved accuracy is required so US forces can use PVT systems and reduce dependence on high cost alternative guidance systems.

4.2.2.7 Signal Power. Future PVT systems shall provide the average received signal with sufficient power to adequately support all users.

4.2.2.8 Surveying. Surveying applications can include such operations as construction, boundary determination, science and research, environmental protection, and agriculture where a generic geographical layout is desired. Requirements exist today for accuracies down to 1 mm, both horizontal and vertical, for some of these applications. Future PVT systems must support one meter horizontal accuracy in real-time, based solely on broadcast information with no augmentation. Near real-time accuracies should be available down to 2 cm horizontal and 4 cm vertical. PVT systems should also provide orbit, atmosphere, and clock corrections either in real-time, or within 24 hours. Although users are able to use augmentation systems for certain accuracies today, a desire has already been identified for future PVT systems to support real-time centimetric accuracy without augmentation.

4.2.2.9 Response Time. Certain tracking applications require responsive positioning and navigation services. Applications such as law enforcement, environmental and marine research, search and rescue, automated vehicle movement, marine navigation, mine warfare, and many other military applications require this information in near real-time in order to complete their missions safely and efficiently. Response time on the order of 1 to 5 seconds is often critical in these applications.

4.2.2.10 Law Enforcement. To support law enforcement requirements, there is a need to provide 1 meter accuracy in tracking individuals wearing court ordered "ankle bracelets." This requirement extends to coverage in buildings and tunnels. Communications operators need to locate questionable RF emitters. Using a PVT system to assist this effort should provide accuracy to less than one meter.

4.2.2.11 Oil/Mineral Studies. There is a need for greater position accuracy than currently provided by DGPS systems for civil users over larger geographical areas.

4.2.3 Rationale.

Many users require substantially better position accuracy than can be provided by the current GPS SPS or PPS. Enhanced accuracy will improve the usefulness of any PVT system thus expanding applications and potential economic benefit.

4.2.3.1 Air Navigation. Civil aircraft navigation performance requirements are determined by the phase of flight and aircraft relationship to terrain, to other aircraft, and to the air traffic control process. Aircraft separation criteria, established by the FAA, take into account limitations of the navigational service available and, in some airspace, the Air Traffic Control surveillance service. Aircraft separation criteria are influenced by the quality of navigational service, but are significantly affected by other factors as well. The criteria relative to separation require a high degree of confidence that an aircraft will remain within its assigned volume of airspace. The dimensions of this volume are determined, in part, by a stipulated probability that performance of the navigation system will not exceed a specified error.

4.2.3.2 Marine Navigation. Civil marine navigational performance requirements are determined by the general type and size of the vessel, the activity in which it is engaged, and the geographic region in which it operates. Safety requirements for navigation performance are dictated by the physical constraints imposed by the environment and the vessel, and the need to avoid the hazards of collision, ramming, and grounding. The pilot of a vessel in restricted waters must direct its movement with great accuracy and precision to avoid grounding in shallow water, hitting submerged/partially submerged rocks, and colliding with other craft in congested waterways. Unable to turn around, and severely limited in the ability to stop to resolve a navigational problem, the pilot of a large vessel (or a tow boat and barge combination) may need accuracy to within a few feet while navigating in this environment. Economic considerations may lead to additional requirements. For example, navigation accuracy (beyond that needed for safety) is particularly important to the economy of large ships with high hourly operating costs. For fishing and oil exploration vessels, the ability to locate precisely and return to productive or promising areas while avoiding underwater obstructions or restricted areas provides important economic benefits. Search and Rescue effectiveness is similarly dependent on accurate navigation in the vicinity of a maritime distress incident.

In such activities as marine scientific research, hydrographic surveying, commercial fishing, and petroleum or mineral exploration, as well as in Navy operations, there may be a need to establish position in the coastal area with much higher accuracy than that needed for safety of general navigation.

For safe general navigation under normal circumstances, requirements for the accuracy and frequency of position fixing on the high seas are not very strict. These minimum requirements permit reasonably safe oceanic navigation, provided the navigator understands and makes allowances for the probable error in navigation, and provided that more accurate navigational service is available as land is approached.

Economic efficiency in transoceanic transportation, special maritime activities, and safety in emergency situations requires or benefits from navigational accuracy higher than that needed for safety in routine, point-to-point ocean voyages.

For system planning, the USG seeks to satisfy minimum safety requirements for each phase of navigation and to maximize economic utility of service for users. Since the vast majority of marine users are required to carry only minimal navigational equipment, and even then do so only if persuaded by individual cost/benefit analysis, this governmental policy helps to promote maritime safety through a simultaneous economic incentive. The USG does not recognize an absolute commitment to satisfy these requirements, but does endeavor to meet them if their cost can be justified by benefits which are in the national interest.

4.2.3.3 Land Navigation. Civil land navigation requirements are driven by many different applications. PVT systems are used for automatic vehicle location, automated vehicle monitoring, automated dispatch, surveying, roadway navigation in general transportation, emergency services, and the transportation of hazardous materials.

Since 1980, geodetic surveyors have used GPS carrier phase signals, both L1 and L2, to measure baseline vectors to the centimeter-level of accuracy and occasionally to the millimeter level. Today, surveyors routinely measure 5, 50, 500, and 5000 kilometer (km) baselines to centimeter accuracy in all components.

The Environmental Protection Agency (EPA), for example, has requirements for 3-5 meters accuracy for location of sites (factories, landfills, sewage plants, etc.), 3-5 meters for location of items (outfalls, wells, stacks, etc.), submeter for sampling points (especially soils, sediments), and millimeter for water levels (especially groundwater in level land). The EPA also needs to be able to do field work with 1-5 minute data collection times.

4.2.3.4 Space Navigation. Space navigation performance requirements are derived from a need to accurately track spacecraft. The National Aeronautics and Space Administration (NASA) intends to use GPS as its operational system on future missions. The International Space Station (ISS) is being designed to use GPS for navigation, attitude determination, and UTC distribution. GPS will support onboard ISS system control functions as well as various experimenter data capture processes. By 2000, the Space Shuttle will use GPS in both its on-orbit operations and the descent phases of flight, and may use GPS during the ascent phase shortly after the turn of the century. NASA, the military, and the commercial space industry use GPS for earth observation, space research, and communications to reduce costs of operations, as well as enable new levels of on-orbit autonomy.

Where scientific data position accuracy is required with precision greater than that readily available from the GPS receiver onboard a spacecraft, a refinement of post-pass orbit data is used. NASA has developed post-pass orbit data processing techniques using GPS on the TOPEX/POSEIDON satellite that provides high accuracy. In order to accomplish this, GPS range and phase observables must be downlinked with scientific data.

In addition to NASA, US industry plans to use GPS for satellite navigation, attitude determination, and precise time. The civil use of GPS for satellite operation has already begun and will accelerate in the near future as many of the new Low Earth Orbit (LEO) communication satellite constellations make use of GPS in their satellites.

4.2.3.5 Military Navigation. Military navigation performance requirements include those civil requirements necessary to operate in nationally and internationally controlled airspace, on the high seas, in coastal areas, and in space. Additionally, military forces must be prepared to conduct operations anywhere in the world, in the air, on and under the sea, on land, and in space. Military planning must also consider operations in hostile environments. Future PVT systems must be capable of providing the signals to meet the requirements for JPALS, GANS, and GATM as they become operational.

4.2.3.6 Precision Munitions. Improved accuracy would improve the safety, increase effectiveness, and reduce costs of precision munitions.

4.2.3.7 Fix Rate. Use of PVT systems by dynamic platforms (high performance aircraft, missiles) requires continuous position/velocity fixes to meet the accuracy requirements of the platform.

4.2.3.8 Surveying. There is a need for surveyors in remote areas to be able to use only the broadcast signals in areas where there is no augmentation available. This capability is necessary to support seismic surveys, Geographical Information Systems data acquisition, land navigation, and mapping projects. One millimeter resolution is necessary to support soil movement detection. There is also a need for clock, orbit and atmospheric correction data for post-processing to support high accuracy users in remote areas. Real-time centrimetric accuracy is needed to support precision farming, road surveying, fiber optic cable mapping, and cartography.

4.3 VELOCITY ACCURACY

4.3.1 Definition

Velocity is the time rate of linear motion in a given direction. Velocity accuracy is the degree of conformance between the estimated or measured velocity of a platform at a given time and its true velocity. For users of the PVT system, velocity is derived from the Doppler shift of received signals.

4.3.2 Requirements

The most stringent threshold values for velocity accuracy requirements are in Table 4-3. A complete listing of the requirements, both military and civil, for velocity accuracy are in Appendix A. Where specified, direction accuracy is provided in parentheses.

Table 4-3. Threshold Requirements for Velocity Accuracy

		Source
Subsurface		
Surface	**0.013 m/sec (0.0225°)** 0.05 m/sec	**Ref 39/35** Ref 44
Air	**.03 km/hr** 2 m/sec	**Ref 39** FAA
Space	**0.001 m/sec** 0.0001 m/sec	**SATOPS ADT** NASA JPL

Table 4-4 provides the most stringent objective values for the requirements of each of the different mediums.

Table 4-4. Objective Requirements for Velocity Accuracy

		Source
Subsurface		
Surface	**0.013 m /sec (0.005°)** 0.4 m/sec	**Ref 39/35** Ref 44
Air	**0.03 m/sec** 2 m/sec	**Ref 39** FAA
Space	**< 0.0001 m/sec** < 0.0001 m/sec	**SATOPS ADT** SATOPS ADT

Support of Satellite Operations imposes the following requirements:

Threshold Requirement: The PVT system shall support velocity determination by satellite-based users such that onboard systems shall be able to determine the satellite's velocity to within 0.1 cm/sec. (3 sigma) per axis in real-time.
Objective Requirement: The PVT system shall support velocity determination by satellite-based users such that onboard systems shall be able to determine the satellite's velocity to within 0.1 mm/sec. (3 sigma) per axis.

4.3.3 Rationale

Determination of accurate velocity is required to provide accurate forecasts of arrival time.

4.4 TIMING ACCURACY

4.4.1 Definition

Timing accuracy refers to the concept of what time the receiver thinks it is vs. what UTC (USNO) time is. There are two measures associated with timing accuracy. The first refers to the degree of conformance between the estimated or measured time and UTC (USNO). Time transfer (the transmission of a time signal over a communications medium) is used to provide accurate time signals to remote users. The second measure refers to the precision in determining the interval of time associated with an event. To accomplish this task, an event's start and stop time is measured according to a precise time signal. Variables associated with timing accuracy include inherent clock accuracy, accuracy of the time transfer procedure, and the quality of the receiver.

4.4.2 Requirements

The most stringent threshold values for timing accuracy requirements are in Table 4-5. A complete listing of the requirements, both military and civil, for timing accuracy are in Appendix A.

Table 4-5. Threshold Requirements for Timing Accuracy

		Source
Subsurface		
Surface	**<10 nsec (1 sigma)** 10 nsec	**Ref 4** Ref 44
Air	**<10 nsec (1 sigma)** 5 msec	**Ref 4** FAA
Space	**20 nsec** 0.1 nsec (1 sigma)	**Ref 12** NASA JPL

Table 4-6 provides the most stringent objective values for the requirements of each of the different mediums.

Table 4-6. Objective Requirements for Timing Accuracy

		Source
Subsurface		
Surface	**<10 nsec (1 sigma)** 1 nsec	**Ref 4** Ref 44
Air	**< 10 nsec (1 sigma)** 5 msec	**Ref 4** FAA
Space	**0.01 nsec PP** 0.01 nsec PP	**SATOPS ADT** SATOPS ADT

4.4.2.1 Timing Reference. PVT systems must provide reliable, highly accurate common timing reference to users/customers. The systems must ensure timing accuracy and stability. Frequent timing accuracy evaluation by the operating authority is necessary to ensure the error is kept within limits.

4.4.2.2 Continuous Link. The PVT system must have a continuous link to UTC (USNO) as the timing standard. This is necessary to ensure any "offsets" in time are recognized and corrected. The PVT time source must be tied to UTC (USNO) to support users who rely on a local atomic frequency standard to check reliability of the PVT signal, or who plan to mix PVT-timed elements of a network with elements timed from other sources. Other users who are affected by PVT offsets from UTC (USNO) are astronomers, who, for example, use PVT systems as a time source to observe the rotation rates of pulsars.

4.4.2.3 Clock Offset Error. Regardless of the time transfer technique, the transmission medium typically introduces delays in the transfer, resulting in a time received by the user that is actually offset from UTC (USNO) time. In order to enable accurate positioning, and the relative clock synchronization required for communication and geolocation, it is necessary to accurately communicate this time offset of PVT clocks to the users so that corrections can be made at the receiving end and the required accuracy can be achieved.

4.4.2.4 Timing Support. The PVT Control Segment shall maintain its own time reference. However, to correctly relate that time to UTC (USNO), near real-time estimates of the PVT-UTC bias offset must be obtained from the USNO. This data will be used by the PVT Control Segment for time transfer and time steering calculations. Threshold: Once per 24 hours. Certain users require more accurate emitter location information to more accurately measure time offsets.

4.4.2.5 Satellite Operations.

Threshold Requirement: The PVT system shall provide real-time information to earth orbiting satellites such that the clock offset error between UTC and the satellite-based user receiver time does not exceed 25 nanoseconds (nsec) (3 sigma).
Objective Requirement: The PVT system shall provide real-time information to earth orbiting satellites such that the clock offset error between UTC and the satellite-based user receiver time does not exceed 0.01 nsec (3 sigma).

4.4.3 Rationale

PVT uses for timing have increased over the years, as have the requirements for increased accuracy. Uses have been developed to provide highly accurate timing for non-associated electronic systems, wildlife migratory studies, power network timing, and time-synchronization between systems. One national telephone company uses Loran-C and GPS extensively for communication network synchronization. Other uses have developed for accurate timing obtained from the PVT signals such as network synchronization, validation of information transmission, tagging of data for time-delayed transfer to data ports, medical and scientific laboratory tests, satellite applications, and fleet monitoring. Navigation is a function of the timing signal, since one nsec equates to about 30 centimeters in distance or about one foot. More uses for the accurate and available signal obtained from the current PVT systems are continually being developed.

4.5 INTEGRITY

4.5.1 Definitions

4.5.1.1 Integrity. There are two aspects that must be addressed by the integrity requirement: 1. System Outage Warning: The ability of the system to provide timely warning to users when the system's signals should not be used by the users for PVT purposes in a part of the user's coverage domain. 2. Malfunctioning Component Determination: The ability of user equipment to determine when a component of the PVT system should not be used as an information source for PVT purposes.

4.5.1.2. Availability of Integrity. Availability of integrity is the percentage of time that the system provides data at the defined level of integrity or provides warning that the level of integrity has dropped below the defined level.

4.5.2 Requirements

All users shall have the ability to monitor the integrity of the PVT system every day, 24 hours per day , in real time throughout the user's coverage domain. PVT System Outage Warnings shall be generated by the PVT system and shall indicate the portion of the user coverage domain to which the warning applies. User determination of a malfunctioning PVT system component may be accomplished through either notification by the PVT system or through passive monitoring of the system by the user equipment, or a combination of both. The most stringent threshold requirements for determination of malfunctioning PVT system components are given in Table 4-7, and represent the time between component malfunction as a PVT information source and determination of the malfunction in the user equipment (user notification as required by application).

Table 4-7. Threshold Requirements for Integrity

		Source
Subsurface		
Surface	Time to alarm: 10 sec	Ref 44
Air	**HMI: $4x10^{-8}$ per approach** **Alarm Limit: 1.1m** **Time to Alarm: 1 sec** $1\text{-}2x10^{-9}$ per approach Time to alarm: 1 sec	**Ref 4** FAA
Space	**Monitor 24 hr/day, 100 % monitoring below 10,000km** **Time to Alarm: 6 sec** Monitor 24 hr/day Time to alarm: 6 sec	**SATOPS ADT/SWC** SATOPS ADT

The most stringent objective requirements for determination of malfunctioning PVT system components are given in Table 4-8, and represent the time between component malfunction as a PVT information source and determination of the malfunction in the user equipment (user notification as required by application.

Table 4-8. Objective Requirements for Integrity

		Source
Subsurface		
Surface	Time to Alarm: 5 sec	Ref 44
Air	**HMI: 4x10^{-8} per approach** **Alarm Limit: 1.1m** **Time to Alarm: 1 sec** 1-2x10^{-9} per approach Time to Alarm: 1 sec	**Ref 4** FAA
Space	**Monitor 24 hrs/day** **Time to Alarm: 3 sec** Monitor 24 hr/day Time to Alarm: 3 sec	**SATOPS ADT** SATOPS ADT

4.5.2.1 Integrity Monitoring.

4.5.2.1.1 PVT System. PVT systems shall provide an integrity system[3] that will interpret signal information and determine if the signal information exceeds the specified performance criteria for that particular phase of operation and then provide timely warning when an out of tolerance situation occurs. The definition of timely warning varies depending on the nature of vehicle involved and its stage of navigation. PVT systems are required to perform worldwide monitoring of their signals and report outages/discrepancies and interference. Integrity thresholds are specified as a probability rate of HMI at a specific alarm limit and time to alarm required by the operation being performed. The integrity function must meet the availability and continuity requirements stated in Sections 4.5 and 4.12, respectively for controlled airspace. Both detection and alarm rate requirements must be met at all times.

4.5.2.1.2 User Equipment. A user must be capable of determining which parts of the system should not be used as a particular PVT System element may be malfunctioning, not the entire PVT System. UE may provide a RAIM capability, with Fault Detection and Exclusion (FDE). When RAIM FDE is being used as the primary integrity source, the system shall alert the operator of projected service outages over the planned route.

4.5.2.2 PVT Signal Monitoring Capability. PVT system control segments shall have the ability to monitor signals passively on a continuous worldwide basis. Each PVT emitter shall be monitored 24 hours per day. Some systems require real- time signal monitoring. Global monitoring coverage is necessary to ensure the navigation signals transmitted meet performance criteria. Updates of system status should be made more frequently (less than one minute) than with current

[3] System includes all segments of PVT. Integrity solutions may involve changes to all segments.

systems. Safety of flight requirements have the most stringent criteria for precise signal monitoring by augmentation systems within defined areas. As a minimum, this criteria includes:

(a) Enroute Through Non-precision Approach: When navigating in controlled airspace, UE shall use any augmentation signals provided to meet integrity requirements for that airspace. The system shall alert the user when the controlled airspace requirements cannot be met.

1) Probability of HMI
2) Time to Alarm
3) Continuity of Navigation
4) Continuity of Fault Detection

(b) Category I Precision Approach Aviation, Precision
1) Probability of HMI
2) Time to Alarm
3) Continuity

(c) Category II Approach
1) Probability of HMI
2) Time to Alarm
3) Continuity

(d) Category III Approach
1) Probability of HMI
2) Time to Alarm
3) Continuity

(e) Probability of Undetected Error

(f) Interference

(Note: Specific values for these requirements are listed in Appendix A.)

4.5.2.3 Precision Landing. For the military, the precision approach integrity requirements are to be defined as part of the JPALS program. Thus, the precision approach values listed in Table B-1 of the MNP prescribe only unaugmented GPS levels. Integrity requirements supporting precision landing will be defined in the JPALS ORD. Civil precision approach requirements are levied in accordance with the FRP.

4.5.2.4 Warning to Users. Under Title 14 USC 81-83, operators of aids to navigation are required to keep the navigation aid in good working order, discover failure, and give warning. PVT systems shall ensure timely warning to users when specific emitters and/or the system is not available for use.

4.5.2.5 Maritime Users. Maritime users also need to know whether the PVT system is operating properly.

4.5.2.6 Space-based Users Interference and Warning. PVT systems must provide an alternate method to ensure a satellite-based user's navigation system can continue to operate in the presence of interference on a particular radio frequency used to obtain PVT information. Since many satellite-based users will not be military, this method should be unencrypted. Also, an alerting scheme for malfunctioning PVT systems must be available to satellite-based users that will enable onboard systems to determine which PVT information sources should not be used due to malfunction of the information source. Space-based PVT user systems shall be notified within 6 seconds of any abnormalities identified in a PVT system by the PVT monitoring system.

4.5.2.7 Other Users. Although impact of anomalies are not safety issues for some users, system failures can have such impact as increased operations cost and region-wide power and communications outages. Future PVT systems should provide the capability to advise users of the PVT system of pending and verified PVT system anomalies.

To support satellite operations, the PVT system shall enable the elimination of erroneous information sources from use by the satellite-based user equipment within 6 seconds of the broadcast of the erroneous information.

4.5.3 Rationale

PVT information is relied upon for safety of life and mission accomplishment (in this context, mission refers to military, commercial, scientific or other mission). In many applications, especially those involving safety of life, it is essential that the end user be notified promptly of system failures. Therefore PVT systems must either positively notify operators when a PVT component fails or is emitting out of tolerance signals or provide a process that will enable user equipment to self-determine that a PVT information source component has malfunctioned. Operators cannot be expected to recognize failures merely by recognizing incorrect navigation information. Integrity monitoring performance depends upon how critical the PVT service is to safety and mission accomplishment.

4.5.3.1 Aviation. Satisfies integrity requirements as stated in the FRP and the MNP.

4.5.3.2 Navigation Signal Monitoring Capability. A monitoring capability is required to allow the control segment to detect and correct satellite signal anomalies. To support civil requirements for warning within six to ten seconds, continuous worldwide monitoring is required.

4.5.3.3 PVT System. The threshold value is a necessary system segment allocation to enable an integrity system to be developed to meet an overall requirement for the average probability of HMI from all causes.

4.5.3.4 Warning to Users. By law, operators of radionavigation aids are required to provide timely warning to users when the system will not be available for use.

4.5.3.5 Space-based Users Interference and Warning. The future use of PVT systems for spacecraft critical functions requires PVT signals be made available for operations throughout the satellite-based user's domain. Therefore satellite-based users must be capable of dealing with signal interference or inaccurate information transmissions from a PVT system. This is especially critical during satellite maneuvering or launch operations.

4.6 AVAILABILITY

4.6.1 Definition

4.6.1.1 Availability. Availability is defined as the percentage of time PVT services are adequate to permit all requirements to be met including determination of position, velocity, or time to a specified level of accuracy over a 24 hour period. It is a function of both the physical characteristics of the environment and the technical characteristics of the PVT systems and facilities.

4.6.1.2 Service Availability. Service Availability is the percentage of time that a user has an adequate number of signals available to allow position, velocity, and time determination at the required accuracy level over a specified time interval and within the coverage domain of the user application.

4.6.1.3 Service Reliability. The reliability of a navigation system is a function of the frequency with which failures occur within the system. It is the probability that a system will perform its function within defined performance limits for a specified period of time under given operating conditions.

4.6.2 Requirements

PVT systems must be available when they are needed. Specific applications may require some systems only be available during certain conditions such as night, adverse weather, etc. Other applications, such as civil and military space systems, may require that the PVT signal be available continuously. For example, there is a current need for 100 per cent availability to support time transfer users. System availability should be specified in appropriate system requirements and specifications documents.

The most stringent threshold values for availability requirements are in Table 4-9. A complete listing of the requirements, both military and civil, for availability are in Appendix A.

Table 4-9. Threshold Requirements for Availability

		Source
Subsurface		
Surface	100 % (of 24 hours)	Ref 44
Air	**99.999% (of 24 hours)** 99.999% of 24 hours	**Ref 4** FAA
Space	**100% over 24 hours** 100% over 24 hours	**SATOPS ADT** SATOPS ADT

Table 4-10 provides the most stringent objective values for the requirements of each of the different mediums.

Table 4-10. Objective Requirements for Availability

		Source
Subsurface		
Surface	100% of 24 hours	Ref 44
Air	**99.999% (of 24 hours)** 99.999% of 24 hours	**Ref 4** FAA
Space	**100% over 24 hours** 100% over 24 hours	**SATOPS ADT** SATOPS ADT

4.6.2.1 Power Grids. Power grids are very large systems that can cover many states and provinces. GPS is used to synchronize the analog-to-digital sampling of voltage and current signals at substations and power plants located tens or hundreds of kilometers apart. GPS is the only practical timekeeping service that can be received in the electrically-noisy substations and power plants. Timing accuracy requirements are modest at the one microsecond level, but 100% availability and reliability are required. In the future, decisions on whether to disconnect major power lines or sacrifice electrical service to a city to save the power grid may be made on measurements that use PVT systems to synchronize measurements.

4.6.2.2 Communications. Include a (one-way) message component for communication between the system operator and the civilian users. It is not reasonable to assume that millions of civilian users will monitor or even be aware of communication services such as Notice to Mariners. Therefore, any important communication from the system operator to the average user must be provided by the PVT message itself.

4.6.2.3 Landing Systems. PVT signals should support 99.9% availability (that is, approximately that of ILS) of precision approach functionality at a given location on earth up to 70 degrees latitude (area where precision approaches to Cat III are conducted). PVT signals should support 99.999% availability on a wide-area basis (that is, the failure that took out the primary airport cannot also take out the alternate). The probability that this precision approach functionality will be lost once the airplane is below 200 feet must be on the order of 1.08E-8 per approach at a given runway end, or about 0.5E-7 per hour on that runway end.

4.6.3 Rationale

The prime reason for the stringent requirements presented in this CRD is safety of life. The mix of current PVT systems provide a very high availability which is necessary to provide continued support to the wide variety of users.

4.7 SECURITY

4.7.1 Definition

Typical man-made threats to a PVT system are detailed in Section 2 and include sabotage, terrorism, physical destruction, jamming, and IW.

4.7.1.1 Security. Security is defined as a condition that results from the establishment and maintenance of protective measures that ensure a state of inviolability from hostile acts or influences. Security also includes measures that prevent the hostile use of PVT services without unduly disrupting or degrading civilian uses.

4.7.1.2 Interference/Jamming. Interference/jamming is the deliberate/non-deliberate radiation, re-radiation, or reflection of electromagnetic energy for the purpose of preventing or reducing an enemy's effective use of the electromagnetic spectrum, and with the intent of degrading or neutralizing the enemy's combat capability.

4.7.1.3 Spoofing. Spoofing is the deliberate radiation, re-radiation, alteration, suppression, absorption, denial, enhancement, or reflection of electromagnetic energy in a manner intended to convey misleading information to an enemy or to enemy electromagnetic-dependent weapons, thereby degrading or neutralizing the enemy's combat capability.

4.7.2 Requirements

System security measures are required to assure mission capabilities during peacetime, war, and intermediate levels of conflict. Transmission of classified or sensitive information must be protected through the use of secure voice and data and control of computer processing operations.

4.7.2.1 Overarching. The PVT system must be able to meet user performance requirements in the presence of degradation, disruption, denial, hostile access, or exploitation by adversaries or natural phenomena. The PVT system must not be vulnerable to any threat that could cause total loss of the PVT service.

4.7.2.2 Protect Aviation Information Systems. A security system must be established that will provide a high level of protection for all aviation information systems. Information systems critical to aircraft, air traffic control and airports should be protected.

4.7.2.3 Propagation Anomalies. Military PVT systems must be free from signal fades or other propagation anomalies within the operating area. The systems must be resistant to both natural disturbances and hostile attacks. The PVT system must be capable of operating through scintillation and severe ionospheric disturbances.

4.7.2.4 Information Control. The system must be capable of preventing or limiting accurate PVT information to all hostile users in an AOR.

4.7.2.5 Jam Resistance. PVT shall have a jam and other interference resistance capability to provide continuous PVT information to the user. Support is defined as detecting, acquiring, maintaining, re-acquiring or providing PVT information to the platform. The threshold is a 30 decibel increase over the current GPS AJ capability. The objective is more than a 30 decibel increase over the current AJ capability, as recommended by the Defense Science Board.

4.7.2.6 Spoofing Protection. Ensure reliable information transmission to the system for proper control and use including protection against spoofing or injection of false or unauthorized information. Military PVT systems must be capable of operating in and through a spoofed environment (threshold). Operate is defined as the ability to detect, acquire, maintain, and reacquire the PVT signal in a spoofed environment[4] to allow systems to meet combat mission requirements.

4.7.2.7 Exploitation. PVT, in concert with other prevention systems, shall be capable of countering or preventing globally and regionally, the exploitation of the PVT signal. This capability must allow countering exploitation without forcing the US to jam its own PVT signals.

4.7.2.8 Anti-Spoof Signal Acquisition. Ensure that authorized users have the means to acquire the anti-spoof signal and do not have to rely on unprotected signals for initial acquisition.

4.7.2.9 Anti-Spoof Signal Tracking. Ensure that authorized users have the means to track the anti-spoof signal in an intentional jamming environment, either hostile or friendly.

4.7.2.10 System Accuracy. The system must have the capability to control the level of system accuracy available to hostile users. All command and telemetry links must be secure.

4.7.2.11 Capability to Operate Under Prevention. PVT shall be capable of detecting, acquiring, maintaining, reacquiring or providing PVT information to platforms during periods of US prevention of the adversarial use of PVT.

---

[4] CJCS MOP 6, Appendix B

4.7.2.12 Encryption. Encryption schemes and key handling for users shall minimize the probability of compromise (reduce handling), reduce the requirement for communications security control of PVT devices, and provide rapid suppression of cryptological variables should compromise occur.

4.7.2.13 Algorithm Access. System security must be adequate to protect access to system algorithms and any classified data. The PVT system shall enable authorized satellite-based users to avoid performance degradation of PVT information in a stressed environment. All satellite-based users supporting national security missions shall be equipped to operate in a stressed environment.

4.7.3 Rationale

4.7.3.1 Increased Dependence. The multiplication of GPS applications within the US Armed Forces dramatically increases both the importance of PVT systems for military activities and the dependence of these organizations on such systems. This dependence increases the need for effective anti-jamming and anti-spoofing capabilities.

4.7.3.2 Adversarial Use. The unencrypted GPS coarse acquisition (C/A) code still provides adversaries with an accuracy of 100 meters, which would still be more than adequate to deliver chemical, biological, or even explosive weapons, if creating terror in a city is the enemy's objective. Further, any enemy encountered is not likely to share the US military's interest in limiting collateral damage. The PVT system must take the necessary steps to provide the level of security for operations in any environment at any time. There must an ability to prevent access to all aspects of the PVT system to hostile elements. The only countermeasure currently available to US Forces is jamming its own signal. This technique denies US use and violates the requirements of the PDD to allow friendly use of the PVT system. From a safety perspective, the system must avoid vulnerability to interference.

4.7.3.3 Spoofing and Jam Resistance. Systems should be as survivable and endurable as the forces and weapon systems they support including hostile attack, EMP, and natural phenomena. Multiple studies have identified current GPS AJ capabilities as inadequate. Future jamming environments will likely be more severe. Increasing PVT system AJ capabilities by 30 decibels or more would force an adversary to use a jammer that had enough output power it would be easy to locate and target the jammer.

4.7.3.4 System Security. Required to protect the PVT signal availability, anti-spoof, and accuracy calculation algorithms.

4.8 CONTINUITY OF SERVICE

4.8.1 Definitions

4.8.1.1 Continuity of Service. Continuity of service (COS) is the ability of a PVT system to provide required service over a specified period of time without interruption. The level of continuity is expressed in terms of the probability of not losing the radiated signals.

Continuity of Service is measured in terms of: (1) ranging signal failure frequency; (2) failure duration; (3) failure magnitude and behavior; (4) distribution of user population around the globe; (5) probability that the failed satellite is used in the position solution; and (6) effect that the failure has on the position solution, given the failed satellite's contribution to solution geometry and the receiver's response to the failure condition.

4.8.1.2 Continuity of Navigation. Continuity of navigation is the ability of the system to provide an accurate signal over a specified period of time without loss of accuracy. The level of continuity is expressed in terms of the probability of not losing the accuracy of the radiated signal. Continuity of navigation is measured only in terms of the frequency of failure of signal accuracy. (See 4.6.1.3 Service Reliability.)

4.8.1.3 Continuity of Fault Detection. Continuity of fault detection is the ability of the system to provide a required level of integrity of a signal over a specified period of time without loss of integrity. The level of continuity is expressed in terms of probability of not losing the required level of integrity of the radiated signal. Continuity of fault detection is measured only in terms of the frequency of failure of signal integrity.

4.8.1.4 Difference Between Continuity of Navigation, Continuity of Fault Detection, and Continuity of Service. Continuity of Navigation (also known as Continuity of Accuracy under RNP) and Continuity of Fault Detection (also known as Continuity of Integrity under RNP) are subsets of Continuity of Service. Continuity of Service indicates all operations will have continuity, reflecting the frequency with which operations may fail and the amount of time the operations will be down. Continuity of Navigation and Continuity of Fault Detection are concerned only with the frequency that accuracy and integrity will fail, but not with the duration.

4.8.2 Requirements

The most stringent threshold values for continuity of service requirements are in Table 4-11.

Table 4-11. Threshold Requirements for Continuity of Service

		Source
Subsurface		
Surface		
Air	**10^{-8} per hour** 1-6x10^{-6} (any 15 sec priod)	**Ref 4** FAA
Space		

Table 4-12 provides the most stringent objective values for the requirements of each of the different mediums.

Table 4-12. Objective Requirements for Continuity of Service

		Source
Subsurface		
Surface		
Air	**10^{-8} per hour** 1-6x10^{-6} (any 15 sec priod)	**Ref 4** FAA
Space		

The discussions that follow provide the basis for designating the most stringent values in the previous tables. A complete listing of the requirements, both military and civil, for continuity of service are in Appendix A.

The PVT design must identify: (1) statistical departures from nominal system ranging accuracy; (2) a navigation message structure or content violation which impacts the receiver's navigation message processing capabilities; and (3) a ranging signal RF characteristic, navigation message structure or navigation message contents violation that impacts the receiver's minimum ranging signal reception or processing capabilities.

4.8.2 1 Enroute through Non-Precision Approach. The probability of loss of COS for the navigation system, for outages affecting multiple aircraft, shall be no more than 10^{-8}/ hour for every location and time.

4.8.2 2 Precision Approach. Aircraft UE, in conjunction with augmentations, shall provide a probability of the loss of COS of 5.5 X 10^{-5} per approach. For precision approaches to ships, COS for the last 12 seconds of the approach shall equal the HMI rate.

4.8.2.3 Satellite Operations. The future PVT system shall provide continuous position, precise time, and attitude determination support to satellite-based users 24 hours per day every day. This continuity of service shall include the ability of satellite-based users to continue operations during periods of interference on any single data link used for transfer of position, time, and attitude determination information by utilization of an alternate data link for receiving the information.

4.8.3 Rationale

Users must have confidence the PVT system will operate properly during the time they need it. They must also be confident the system will alert them if a problem develops during use.

4.9 AFFORDABILITY

4.9.1 Definition

PVT system operations can be viewed as an overhead cost in that it provides a capability to a user to perform a mission. As with any overhead cost, it behooves the system owner/operator to minimize costs where ever possible.

Cost can include development and procurement, but there are potential savings in PVT system operations in the day to day operating expenses. These are typically (but not necessarily limited to) manpower, training, facilities, hardware/software maintenance, and leased assets.

4.9.2 Requirements

Economic Performance. The PVT system must provide an economic performance and benefit enhancement. Budgetary pressures, coupled with the US commitment to provide PVT signals indefinitely, force the need for an affordable solution. With the wide impact on day to day life that the PVT system has, there is a need for the PVT system to provide capabilities at an affordable level for the owners and operators as well as for all users. The PVT system must be cost-effective and at the same time must provide service of useful quality to all classes of users. Any changes to the PVT system shall be assessed for impact on the affordability of user equipment. Required UE modifications must be held to a minimum.

4.9.3 Rationale.

Accurate radionavigation systems can contribute to better productivity and decreased delay in transit. The need to conserve energy resources and to reduce costs provides powerful incentives for increased transportation efficiency, some of which can come from better navigation systems. With the current budgetary constraints, costs have become a key driver in fielding or modifying any system. This will not likely change in the near future. Commercial endeavors require profit in a finite amount of time and with the current rate of technological evolution, this time period is reducing.

Multi-user (outside the DoD) systems are uncommon for the DoD. Seeking economic benefits from a system are unusual in DoD planning. Yet, potential PVT system economic benefits (outside the DoD) are substantial. Making these benefits available to all users as soon as possible is important. Development and deployment schedules must consider benefits that can be achieved by early deployment. This means the selected architecture should be available in a reasonable amount of time, without having to stretch out procurement due to high cost and high risk.

4.10 COVERAGE

4.10.1 Definition

The coverage provided by a radionavigation system is that surface area or space volume in which the signals are adequate to permit the users to determine position, velocity, and timing to a specified level of accuracy. Coverage is influenced by system geometry, signal power levels, receiver sensitivity, atmospheric noise conditions, and other factors that affect signal availability.

4.10.2 Requirements

The most stringent threshold values for coverage requirements are in Table 4-13. A complete listing of the requirements, both military and civil, for coverage are in Appendix A.

Table 4-13. Threshold Requirements for Coverage

		Source
Subsurface	**TBD** Worldwide through all operating environments	 Ref 44
Surface	**Worldwide through all operating environments** Worldwide through all operating environments	Ref 12 Ref 44
Air	**Worldwide through all operating environments** Global (per availability & COS requirements)	Ref 12 FAA
Space	**Global to geostationary altitude** Global to geostationary altitude	**SATOPS ADT** SATOPS ADT

* Worldwide includes 90 degrees south to 90 degrees north latitude and 0 degrees to 359 degrees longitude.

Table 4-14. Objective Requirements for Coverage

		Source
Subsurface	**Worldwide* through all operating environments** Worldwide through all operating environments	Ref 12 Ref 44
Surface	**Worldwide through all operating environments** Worldwide through all operating environments	Ref 12 Ref 44
Air	**Worldwide through all operating environments** Global (per availability & COS requirements)	Ref 12 FAA
Space	**Global to twice geostationary altitude** Global to twice geostationary altitude	**SATOPS ADT** SATOPS ADT

* Worldwide includes 90 degrees south to 90 degrees north latitude and 0 degrees to 359 degrees longitude.

4.10.2.1 Canopy Penetration. The PVT system should provide improved coverage in forest and canyon areas, especially in northern latitudes. The system should also support the reception of signals inside buildings.

4.10.2.2 Satellite Operations. The PVT system should provide coverage to support position and velocity information to all satellites below 10,000 km altitude. The PVT system shall support satellite-based users in performing autonomous positioning, determining satellite attitude, and marking precise time, 24 hours per day, for satellites in any LEO, out to Highly Elliptical Orbit (HEO), where the apogee of a HEO does not exceed twice the GEO apogee.

4.10.3 Rationale.

Specific constellation design objectives are: (1) provide continuous global coverage with specified geometry and mask angle constraints, (2) minimize coverage sensitivity to expected satellite orbital drift characteristics, and (3) mitigate the effects on service availability of removing any one satellite from service.

Several factors affect GPS constellation coverage. These factors must be taken into consideration in the constellation design. The factors are: (1) The difference between the planned orbit and the orbit actually achieved during the launch and orbit insertion process, (2) orbit variation dynamics, and (3) frequency and efficiency of satellite stationkeeping maneuvers.

The information provided by the PVT system is intended to support terrestrial users worldwide, as well as space users from LEO to Geostationary /Geosynchronous Earth Orbit. There is growing dependence on current PVT systems in all facets of everyday life. PVT signals are being used in steep canyon environments, urban and rural, in such tasks as tracking vehicle, individual and wildlife movement. People are discovering new uses for the GPS signal as shown in Table 1-2.

Military forces must be prepared to project global presence. To enhance the role of all military forces in exerting presence, military forces must incorporate technological innovations into all operations. By providing worldwide coverage, PVT will enhance the ability to monitor and assess global conditions rapidly and efficiently. PVT will allow commanders improved transport technology to enable rapid and accurate deployment of resources worldwide. Weapon system technology enhancements are dependent upon PVT to provide the coverage necessary for accurate weapons delivery.

4.11 SUPPORTABILITY

4.11.1 Definition

This characteristic indicates the degree to which all operations and logistics elements combine to satisfy system control and dependability requirements. It incorporates such diverse elements as reliability, maintainability, manpower and training, supply support, packaging, handling, transport, support equipment, technical data, and facilities. It also includes control of the PVT system.

4.11.2 Requirements

4.11.2.1 Standard Logistics Infrastructure. This PVT system, to include the user equipment, will make maximum use of standard Agency-specific logistics infrastructure, minimize demands on personnel, and the environment, and be readily adaptable, so that if needed, it can be modified for use with any follow-on systems. Supportability ensures the system will be available, in-place, and durable.

4.11.2.2 Reliability & Maintainability. The reliability of worldwide PVT system components shall be determined as a function of overall cost and performance requirements. Support of PVT components should be simplified and compatible with the existing Agency supply system.

Emphasis must be placed on improving maintenance efficiency, including integrated diagnostics, and simple remove and replace maintenance and upgrade actions."

4.11.2.2.1 Space and Control. The space and control segment should emphasize robust design, commonality, highly reliable components and integrated diagnostics. The space segment equipment should be designed to survive potential operational and launch rigors. The control segment equipment should be designed for simple remove and replace maintenance actions and to survive potential operational rigors and minimize transport requirements. The control segment should be capable of providing operational control and monitoring performance of the PVT system 100 per cent of the time.

4.11.2.2.2 User Equipment. The UE segment should emphasize robust design, commonality, highly reliable components, integrated diagnostics, and simple remove and replace maintenance actions. UE should be designed to survive potential operational and handling rigors and minimize transport requirements. It is also expected to have predicted reliabilities orders of magnitudes higher than its predecessors. The UE reliability thresholds and mature specification requirements should be increased to account for the significantly higher predicted reliabilities.

4.11.2.3 Training and Operation. Training will be incorporated into training programs as established by the cognizant agency or department. Instruction shall produce the required operational skills for normal and anomalous/emergency operations.

4.11.2.4 Maintenance. Maintenance of the PVT system shall be established by the owners/operators of components of the PVT system. The owners shall be responsible for providing the requisite maintenance training needed for operations personnel to maintain the component.

4.11.2.5 System Safety. System safety programs will be conducted in accordance with appropriate service/agency directives. The program will ensure orbital safety concerns are addressed in systems engineering. For the ground segment, Federal Occupational Safety and Health Administration regulations and appropriate industry standards will be implemented.

4.11.2.6 Simulators. Simulators shall be provided to train operations and maintenance crew personnel.

4.11.3 Rationale.

Supportability is important to PVT systems and its implementation varies by PVT component. Individual supportability requirements for PVT system components will be identified in component ORDs.

4.11.3.1 Standard Logistics Infrastructure. Conformance with the practices established by standard logistics infrastructures ensures that new systems and equipment acquired will exhibit cost-effective, supportable design with emphasis on optimizing logistics resources.

4.11.3.2 Training and Operation. Training of personnel on the operations of the PVT system is essential to prevent reduction in system availability and reliability.

4.11.3.3 Maintenance. With the increased dependence on PVT systems, especially GPS, maintenance concepts are needed to ensure that the PVT systems operate at the peak of reliability and availability.

4.11.3.4 System Safety. Safety needs to be addressed in all phases of the PVT system to ensure that the system performs to the levels required.

4.11.3.5 Simulation Capability. High fidelity simulation is required to support training, planning, testing, and war-gaming to prevent operational errors and to support engineering and analysis.

4.12 SURVIVABILITY

4.12.1 Definition

Survivability is defined as the capability to avoid or withstand the impact of a hostile environment (man-made or natural) without suffering an abortive impairment of the ability to accomplish the most critical mission requirements.

4.12.2 Requirements

In general, the PVT system must be as survivable as the missions and forces it supports.

4.12.2.1 Natural Environment Protection. Ensure that space-based systems, specifically space vehicles and control stations, are survivable against the natural environment of near-earth space (ionospheric scintillation, natural radiation belts, radiation events due to solar flares, and galactic cosmic rays) and against man-made environments. The space-based system must be capable of operating without degradation in potentially hostile environments (enhanced radiation belts due to detonation of nuclear weapons above the atmosphere, directed energy weapons from the ground, etc.).

4.12.2.2 Wartime Requirements. The mission of PVT is to support user requirements through all levels of conflict, consistent with the forces supported.

4.12.2.3 Biological and Chemical Survivability. The PVT design will meet or exceed biological and chemical survivability requirements consistent with all levels of conflict.

4.12.2.4 Continuous Control Capability. The PVT system must have a 24-hour control capability.

4.12.2.5 Satellite Operations. The PVT system shall be designed such that satellite-based users supporting national security missions shall be able to complete their mission in the presence of intentional interference, spoofing, or temporary loss of PVT system ground control capability. In addition, the PVT system shall be designed such that all satellite-based users shall be capable of surviving unintentional or natural interference.

4.12.3 Rationale.

The survivability of certain PVT systems is vital to US national interests. It is necessary to identify and protect tactical and strategic minimum essential capabilities that must be relied upon even in the face of the most capable adversaries. The US must preclude the ability of an adversary to incapacitate our PVT capabilities.

4.13 INTEROPERABILITY

4.13.1 Definition

Interoperability is defined as the ability of the PVT system to provide GPS Standard Positioning Service in accordance with the PDD; to be compatible with legacy UE; and to provide seamless PVT information, referenced to a common grid, via the system of systems.

4.13.2 Requirements

4.13.2.1 Civil/Military Interoperability. The basic capabilities to permit common use and common operational procedures by civil and military users should be provided. The highest degree of commonality and system utility between military and civil users is sought through early consideration of mutual requirements. Civil and military PVT equipment should be compatible to the extent feasible. In addition, the number of transmission formats should be kept to a minimum in meeting diverse civil requirements. There is merit in this approach since many applications are the same (or similar) and coordinated purchases could result in more capable UE, at lower cost, for both groups.

4.13.2.2 International Acceptance. Navigation services and systems should be technically and politically acceptable to diverse groups, including NATO and other allies, ICAO, International Telecommunications Union, and International Maritime Organization (IMO).

4.13.2.3 Data Referenced to a Common Grid. In order to establish a common grid for reference, the navigation, position, and velocity information must be referenced to a commonly used geolocation standard. Data is currently referenced to the World Geodetic Survey 1984 (WGS-84). Data for future systems must be referenced to an agreed-upon standard utilized or established by the NIMA and updated as needed. The system must provide a signal that can be translated to any common datum.

4.13.2.4 Operations . All changes to the PNT system that affect the existing GPS will be made in a manner such that the structure and performance of the existing system signals will not change.

New PVT systems must support backward compatibility and work with current UE for at least the near and mid term. For the far term, new signals/signal structures may require new UE. If so, a transition period must be established over such a length of time as to allow affordable replacement of UE. Protection requirements may require acquisition of new UE, if the mission requires protected services. If the mission does not require protected services, existing UE must continue to provide PVT.

4.13.2.5 Integration with Service/Agency Programs. Integration into Service/Agency-specific command, control, communications, and intelligence programs will be dependent upon agency/service needs. Sufficient technical system information must be made available in order for users to integrate the PVT signals into their applications.

4.13.2.6 Integrated Displays. Close coupling of the PVT system signal will be required with geospatial information for navigation. The PVT system should provide information at the level of detail that users need. Automatic updates of the information should be available so that the user will have current accurate information. Military UE must support standard military and commercial interfaces to provide PVT information for the given application.

4.13.2.7 Common Frequency. Primary and augmentation PVT systems elements should operate on the same (or compatible) frequencies, with the intent of reducing the size, quantity and cost of receivers and additional equipment needed for PVT needs.

Rationale: Many applications currently require moving additional equipment to remote locations to meet the accuracy requirements of the operation. This necessity can be reduced by a fully integrated PVT system operating on compatible standards.

4.13.2.8 Regional and Local Systems. Future global PVT systems must provide a practical interface to regional and local systems such as WAAS, LAAS, and JPALS.

4.13.2.9 Satellite Operations. Due to the inaccessibility of spaceborne receivers on unmanned spacecraft and the timelines associated with developing new satellite-based user equipment, any changes in format or performance characteristics of the PNT system must be evaluated for impacts on the installed and planned set of satellite-based users.

4.13.3 Rationale

In the future, electronic displays will replace maps for use in navigation. The user will require the latest, most accurate information available.

L1 C/A backward compatibility is extremely important in order to continue service to the likely millions of low cost product users.

The goals of interoperability and cost minimization of user equipment influence the search for an international consensus on a selection of radionavigation systems. For civil aviation, the ICAO establishes standards for internationally used radionavigation systems. For the international maritime community, a similar role is played by the IMO. Traditionally, IMO has been less stringent in establishing radionavigation requirements for the maritime community than ICAO has been for the aviation community. The IALA also develops international radionavigation guidelines. IMO is reviewing existing and proposed radionavigation systems to identify a system or systems that could meet the requirements of, and be acceptable to, members of the international maritime community.

4.14 RECOMMENDED KEY PERFORMANCE PARAMETERS

The following required system characteristics are further delineated as KPPs. Actual, affordable values associated with the KPPs will be determined by SMC through the efforts associated with the Acquisition Master Plan. Since each KPP encompasses multiple requirements, the critical item is listed for each KPP, when required.

4.14.1 Position Accuracy

Position accuracy requirements are driven by many different applications. Many users require substantially better position accuracy than can be provided by the current GPS SPS or PPS. Position accuracy is critical to precision approach, close air support, mine laying, precision guided munitions delivery, and delivery of conventional high velocity penetrator weapons for attack of hard and deeply buried targets. Enhanced accuracy will improve the usefulness of any PVT system thus expanding applications and potential economic benefit. Failure to provide a PVT capability that meets position accuracy requirements would nullify the policies of the PDD.

4.14.2 Velocity Accuracy

Accurate velocity indication is critical to multiple users, both military and civil.

4.14.3 Timing Accuracy

Precise time is essential to users who must time-synchronize other systems. Today, GPS has evolved into the primary system by which the USNO maintained reference time is distributed for most DoD systems. It is anticipated that, in the future, even more users will rely on these PVT systems for establishing precise time.

4.14.4 Integrity

PVT systems must positively notify operators when a system fails or is emitting out of tolerance signals. Military, commercial, scientific and other mission users rely upon accurate, usable PVT information for safety of life and mission accomplishment. Operators of radionavigation aids are required by law to provide timely warning to users when the system will not be available for use.

4.14.5 Availability

Position, timing, and velocity accuracy provide three-dimensional predictable, relative, and repeatable information to authorized users. Accuracy relies on Availability. Without a high Availability, PVT accuracy for users could suffer. Integrity is essential to provide adequate safety for aviation and other uses.

4.14.6 Security

The PVT system must take the necessary steps to provide the level of security for operations in any environment at any time.

4.14.7 Continuity of Service

Continuity of Service is mandatory. The PVT system must operate properly when needed.

4.14.8 Affordability

Cost must be considered equally with other system characteristics.

4.15 TRANSITION ISSUES

4.15.1 Continuity of Operations

This issue relates to issues/requirements that must be addressed to support operations while new and legacy PVT systems are operational.

User concerns with having to rely on one PVT system must be balanced with the need to consolidate and reduce the number of systems. The constantly changing radionavigation user profile and rapid advancements in systems technology require that the PVT concept remain as dynamic as the issues addressed.

4.15.2 Backward Compatibility

Modification and transition of systems should occur in an orderly manner to accommodate technical improvements. Only those systems that serve a significant number of users and provide the economic benefits in excess of costs should continue in operation. In some cases duplicate systems will have to be maintained for safety reasons and to allow adequate time for the transition to newer more accurate systems; however, older systems must be evaluated to determine whether or not their level of use is cost-effective.

4.15.3 Force Structure

Manpower and facility requirements based upon engineering, operational, and maintenance considerations include: (1) equipment dimensions, (2) space availability, (3) system safety, (4) accessibility, (5) worldwide coverage, (6) physical security requirements, (7) the need for continuous around-the-clock operations, and (8) multi-service, multi-national agreements.

APPENDIX A

POSITION, VELOCITY, AND TIME REQUIREMENTS

POSITION ACCURACY - MILITARY									
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**								**SOURCE**
	THRESHOLD				**OBJECTIVE**				
I. EARTH AND ATMOSPHERE									
IA LAND									
IA1 SURFACE									
IA1e ARMY LAND	**Horizontal Position (m-CEP)**	**Vertical Position (m-LEP)**	**Direction (Mils-LEP)**	**Response Time (Minutes - 1 Sigma)**	**Horizontal Position (m-CEP)**	**Vertical Position (m-LEP)**	**Direction (Mils-LEP)**	**Response Time (Minutes - 1 Sigma)**	REF 35
IA1e(1) CHEMICAL	10.5 m (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
(2) ENGINEER	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
(2)(a) MINE NEUTRAL	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
(2)(b) MINE DISPENSING	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
(2)(c) GAP CROSSING	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA1e(3) FIELD ARTILLERY	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
(3)(a) MLRS	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
(3)(b) HOWITZER (TOWED)	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
(3)(c) HOWITZER (SELF-PROPELLED)	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
(3)(d) MORTARS	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
(3)(e) FIST-V	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
(3)(f) FORWARD OBSERVER	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
(3)(g) ARTILLERY RADAR	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
(3)(h) MORTAR LOCATING FIREFINDER RADAR	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35

POSITION ACCURACY - MILITARY									
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**								**SOURCE**
	THRESHOLD				**OBJECTIVE**				
	Horizontal Position (m-CEP)	**Vertical Position (m-LEP)**	**Direction (Mils-LEP)**	**Response Time (Minutes - 1 Sigma)**	**Horizontal Position (m-CEP)**	**Vertical Position (m-LEP)**	**Direction (Mils-LEP)**	**Response Time (Minutes - 1 Sigma)**	
IA1e(4) INFANTRY	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA1e(5) MISSILE MUNITIONS	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA1e(6) SIGNAL	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA1e(7) TRANSPORATION (WHEELED VEHICLE)	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA1e(8) SOLDIER SUPPORT	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA1e(9) ARMOR	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA1e(10) MILITARY POLICE	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA1e(11) SPECIAL OPS FORCES	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA1e(12) INTELLIGENCE ELECTRONIC WARFARE	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA1e(13) QUARTERMASTER	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA1e(14) ORDINANCE	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA1e(15) AIR DEFENSE ARTILLERY									
IA1e(15)(a) PATRIOT	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA1e(16)(b) HAWK	10.5 (5 m)	8.7 m (3 m)	1.16 mils (0.4 mils)	100 nsec	2.1 m (1 m)	2.9 m (1 m)	.29 mils (0.10 mils)	10 nsec	REF 35
IA2 SUBTERRANEAN									
IB MARINE									
IB1 NAVAL	**Horizontal Position (m-SEP)**	**Heading (Degrees-LEP)**	**Altitude/Depth (m-LEP)**		**Horizontal Position (m-SEP)**	**Heading (Degrees-LEP)**	**Altitude/Depth (m-LEP)**		
IB1a ENROUTE NAVIGATION									
IB1a(1) PILOTAGE WATERS	72	0.8	1% Depth						REF 39

POSITION ACCURACY - MILITARY

OPERATIONAL ENVIRONMENT/ MISSION	REQUIREMENTS						SOURCE
	THRESHOLD			**OBJECTIVE**			
	Horizontal Position (m-SEP)	**Heading (Degrees-LEP)**	**Altitude/Depth (m-LEP)**	**Horizontal Position (m-SEP)**	**Heading (Degrees-LEP)**	**Altitude/Depth (m-LEP)**	
(2) COASTAL WATERS	72	0.8	1% Depth				REF 39
(3) INLAND WATERS	25	0.8	1% Depth				REF 39
(4) OPEN WATERS	2,400	0.8	5% Depth				REF 39
(5) RENDEVOUS	380	0.8	5% Depth				REF 39
(6) HARBOR NAVIGATION	8						REF 39
(7) DYNAMIC POSITIONING	TBS						
(8) LAW ENFORCEMENT	TBS						
(9) ICE BREAKING	TBS						
(10) SEARCH AND RESCUE	TBS						
IB1b MINE WARFARE	<2 M SEP						REF 4
IB1b(1) NAV IN SWEPT CHANNEL	16						REF 39
(2) DEFENSIVE MINING	16						REF 39
(3) OFFENSIVE MINING	16						REF 39
(4) ANTIMINE COUNTERMEASURES	<2 M SEP						REF 4
(5) GEODETIC REFERENCE GUIDE (WGS-84)	128						REF 39
IB1c SPECIAL WARFARE							
IB1c(1) PARADROP	20	1	50.0				REF 39
(2) SMALL CRAFT	50	1	50.0				REF 39
(3) COMBAT SWIMMING							
IB1c(3)(a) ENROUTE	3	0.5	0.3				REF 39
(b) RENDEVOUS	1	0.5	0.3				REF 39
IB1c(4) LAND WARFARE							
IB1c(4)(a) ENROUTE	3	1					REF 39
IB1c(4)(b) RENDEVOUS	1	1					REF 39
IB1c(5) INSERTION	1	1					REF 39
IB1c(6) EXTRACTION	1	1					REF 39
IB1d TASK GROUP OPERATIONS							
IB1d(1) MANEUVERING IN CLOSE COMPANY	72 (Relative Position)						REF 39

IB1e AMPHIBIOUS WARFARE	**Horizontal Position (m-CEP)**	**Heading (Km/Hr-LEP)**	**Altitude Roll/Pitch**	**Heave (cm-LEP)**	**Horizontal Position (m-CEP)**	**Heading (Km/Hr-LEP)**	**Altitude Roll/Pitch**	**Heave (cm-LEP)**	
IB1e(1) BEACH SURVEYS	185								REF 39

POSITION ACCURACY - MILITARY									
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**								**SOURCE**
	THRESHOLD				**OBJECTIVE**				
(2) LANDING CRAFT	50								REF 39
(3) ARTILLERY	<6								REF 39
(4) RECONNAISSANCE	<5								REF 39
IB1f HYDROGRAPHIC/ OCEANOGRAPHIC SURVEYS									
IB1f(1) HYDROGRAPHIC SURVEYS	<5 drms	0.8	72	5					REF 39
(2) OCEAN SURVEYS	90 drms	0.03	105	30					REF 39
(3) OCEANOGRAPHIC SURVEYS	100 drms								REF 39
IB1g GEOPHYSICAL SURVEYS									
IB1g(1) DEEP OCEAN AREAS	90 0.05	0.03	105/ 105	30					REF 39
IC AIR	**Horizontal Position (m-CEP)**		**Altitude (m-LEP)**		**Horizontal Position (m-CEP)**		**Altitude (m-LEP)**		
IC1 DOD AVIATION									
IC1a ENROUTE									
IC1a(1) AIRWAY	3 nm (95%)		-						REF 39
(2) OCEANIC	12.6 nm (95%)		-						REF 39
(3) LOW LEVEL	50 (95%)		± 22.5						REF 39
(4) RNAV	3 nm (95%)		-						REF 39
(5) TERMINAL	2 nm (95%)		-						REF 39
IC1b APPROACH/LANDING									
IC1b(1) NONPRECISION									
IC1b(1)(a) LAND	.6 nm (95%)		-						REF 39
(b) SEA	± 12 (95%)		± 3						REF 39
IC1b(2) PRECISION									
IC1b(2)(a) LAND	± 17.1 (95%)		± 1.7						REF 39
(i) PFE (Horizontal)	5.5				4.4				REF 4
(ii) PFE (Vertical)	1.8				1.3				REF 4
(iii) PFN (Horizontal)	3.4								REF 4
(iv) PFN (Vertical)	0.5				0.4				REF 4
(v) CMN (Horizontal)	3.6								REF 4
(vi) CMN (Vertical)	0.7								REF 4
(b) SEA	± 0.6 (95%)		± 0.6						REF 39
	Horizontal Position (m-CEP)		**Altitude (m-LEP)**		**Horizontal Position (m-CEP)**		**Altitude (m-LEP)**		
(i) PFE (Horizontal)	.35				.2				REF 4
(ii) PFE (Vertical)	.35				.2				REF 4
(iii) PFN (Horizontal)	.25				.16				REF 4

POSITION ACCURACY - MILITARY					
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**				**SOURCE**
	THRESHOLD		**OBJECTIVE**		
(iv) PFN (Vertical)	.2		.1		REF 4
(v) CMN (Horizontal)	.25		.16		REF 4
(vi) CMN (Vertical)	.2		.1		REF 4
IC1b(3) UNPREPARED SURFACE	± 12.5 (95%)	-			REF 39
IC1c AIR DROP	50.0	91.0			REF 39
IC1d AMPHIBIOUS WARFARE					
IC1d(1) TRANSPORT	50	3.0			REF 39
IC1d(2) ATTACK	50	3.0			REF 39
IC1e ANTISUBMARINE/ ANTISURFACE WARFARE	50.0	3.0			REF 39
IC1f ANTIAIR WARFARE	18.1	29.7			REF 39
IC1g STRATEGIC BOMBING					
IC1g(1) CONVENTIONAL	37.5	22.50			REF 39
IC1g(2) NUCLEAR	75.0	22.50			REF 39
IC1h CLOSE AIR SUPPORT/ INTERDICTION	9.0	21.75			REF 39
IC1i ELECTRONIC WARFARE	22.5	22.50			REF 39
IC1j C3	37.5	43.50			REF 39
IC1k MAPPING	50.0	50.00			REF 39
IC1l SEARCH, RESCUE, MED-EVAC INSERTION, EXTRACTION	125.0	21.75			REF 39
IC1m AIR REFUELING	370.0	75.00			REF 39
IC1n MINE WARFARE					
IC1n(1) COUNTERMEASURES	16.0	3.00			REF 39
IC1n(2) MINE LAYING	50.0	3.00			REF 39
IC1o RECONNAISSANCE	18.1	58.00			REF 39
IC1p MAGNETIC SURVEY	20.0	3.00 (MOA)			REF 39
IC1q GRAVITY SURVEY	20.0	3.00 (MOA)			REF 39
IC1r PRECISION GUIDED MUNITIONS	< 2 m SEP				REF 4
IC2 FIX RATE	Continuous	Continuous			REF 12
IC3 FIX DIMENSION	3D plus time sync	3D plus time sync			REF 12
II SPACE	**3D Position**	**Attitude**	**3D Position**	**Attitude**	
IIA UP TO GEOSYNCH					
IIA1 SATELLITE OPERATIONS (Near real-time)	6m	0.1 deg	20 cm	0.01 deg	SATOPS ADT
IIA2 SATELLITE OPERATIONS (Post-processed)	1 cm w/in 72 hrs	0.001 deg w/in 72 hrs	1 cm w/in 1 hr	0.001 deg w/in 1 hr	SATOPS ADT

POSITION ACCURACY - MILITARY					
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**				**SOURCE**
	THRESHOLD		**OBJECTIVE**		
IIB GEO AND BEYOND (Earth Orbiting)					
IIB1 SATELLITE OPERATIONS (Near real-time)	25 m	0.1 deg	10 m	0.01 deg	SATOPS ADT
	3D Position	**Attitude**	**3D Position**	**Attitude**	
IIB2 SATELLITE OPERATIONS (Post-processed)	TBD	TBD	TBD	TBD	SATOPS ADT

POSITION ACCURACY - CIVIL

OPERATIONAL ENVIRONMENT/ MISSION	REQUIREMENTS				SOURCE
	THRESHOLD		OBJECTIVE		
I. EARTH AND ATMOSPHERE					
IA LAND					
IA1 SURFACE	**HORIZONTAL**	**VERTICAL**	**HORIZONTAL**	**VERTICAL**	
IA1a HIGHWAYS					
IA1a(1) NAV & ROUTE GUIDE	20 m		5 m		REF 31
(2) VEHICLE MONITORING	30 m				REF 31
(3) VEHICLE ID	30 m				REF 31
(4) PUBLIC SAFETY	10 m				REF 31
(5) RESOURCE MGT	5 m				REF 44
(6) COLLISION AVOIDANCE	1 m				REF 31
(7) GEOPHYSICAL SURVEY	1 m				REF 44
(8) GEODETIC CONTROL	Sub-meter				REF 31
IA1b RAIL					
IA1b(1) POSITION LOCATION	30 m		10 m		REF 31
(2) TRAIN CONTROL	1 m				REF 31
IA1c TRANSIT					
IA1c(1) VEHICLE C&C	50 m		30 m		REF 31
(2) BUS STOP AUTO VOICE	5 m				REF 31
(3) EMERGENCY RESP	100 m		75m		REF 31
(4) DATA COLLECTION	5 m				REF 31
(5) FLEET MONITORING	35 m		25 m		REF 44
IA1d SURVEYING					
IA1d(1) Geodetic Survey	0.01 m (2 sigma)	0.01 m (2 sigma)			REF 44
(2) Cadastral Survey	0.15 m (2 sigma)	N/A			REF 44
(3) Crustal Motion	0.001 m (2 sigma)	0.001 m (2 sigma)			REF 44
(4) Deformation Monitoring	0.001 m (2 sigma)	0.001 m (2 sigma)			REF 44
(5) GIS (Facilities Management)	0.1 - 1.0 m (2 sigma)	0.1 - 1.0 m (2 sigma)			REF 44
(6) GIS (Natural Resource Management, Endangered Species Studies, etc.)	1.0 - 5.0 m (2 sigma)	1.0 - 5.0 m (2 sigma)			REF 44
(7) Real-time GIS Land Navigation	0.1 - 1.0 m (2 sigma)	0.1 - 1.0 m (2 sigma)			REF 44
(8) Airport Survey - Runway	Horizontal: 30 cm	Orthogonal: 7.5 cm Elliptical: 6 cm	Horizontal: 30 cm	Orthogonal: 7.5 cm Elliptical: 6 cm	FAA
IA1e PEDESTRIAN - AID TO BLIND	< 5 M				REF 44
IA2 SUBTERRANEAN					
	HORIZONTAL	**VERTICAL**	**HORIZONTAL**	**VERTICAL**	

POSITION ACCURACY - CIVIL					
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**				**SOURCE**
	THRESHOLD		**OBJECTIVE**		
IA2a TRAFFIC TUNNELS	1 M				REF 44
IA3 ENVIRONMENTAL					
IA3a SITES	30 m		25 m		REF 44
IA3b STATIONARY SAMPLING PT	5 m		3 m		REF 44
IA3c VARIABLE SAMPLING PT	5 m		0.2 m - 0.5 m		REF 44
IA3d WATER LEVEL	1 m	5 mm	1 m	5 mm	REF 44
IA3e NAVIGATION	1 m	0.1 m	0.1 m	1 cm	REF 44
IA3f SEDIMENT SURVEY (INCLUDING SUBSURFACE (WATER))	0.1 m	0.1 m	0.1 m	1 cm	REF 44
IA4 HEALTH CARE	5 m				REF 44
IA5 LAW ENFORCEMENT	1 m				REF 44
IA6 RECREATION/SPORTS	2 m	2 m	1 m	1 m	REF 44
IA7 FARMING	0.01 m (2 Sigma)	0.04 m (2 Sigma)			REF 44
IA8 EARTHQUAKE RESEARCH	0.015 m (post process)				NASA/JPL
IB MARINE	**All accuracies 2drms**				REF 31
IB1 OCEAN					
IB1a SAFETY OF NAVIGATION	7.4 km within 2 hours		1.8 Km within 15 min		REF 31
IB1b LARGE SHIPS - EFFICIENCY	460 m within 5 min		185 m within 5 min		REF 31
IB1c RESOURCE EXPLORATION	100 m within 1 min		10 m within 1 min		REF 31
IB1d SEARCH OPERATIONS	460 m within 1 min		185 m within 1 min		REF 31
IB2 COASTAL					REF 31
IB2a SAFETY OF NAVIGATION	460 m within 2 min				REF 31
IB2b SAFETY (RECREATION/SMALL VESSELS)	3.7 km within 5 min		460 m within 5 min		REF 31
IB2c FISHING	460 m within 1 min				REF 31
IB2d RESOURCE EXPLORATION	100 m within 1 sec		10 m within 1 sec		REF 31
IB2e SEARCH OPERATIONS / LAW ENFORCEMENT	0.25 m within 1 min				REF 31
IB3 HARBOR ENTRANCE/APPROACH					REF 31
IB3a SAFETY OF NAVIGATION	20 m within 10 sec		8 m within 6 sec		REF 31
IB3b RESOURCE EXPLORATION	5 m within 1 sec		1 m within 1 sec		REF 31
IB3c ENGINEERING & CONSTRUCTION VESSELS	0.1 m within 2 sec	5 m within 2 sec	0.1 m within 1 sec	5 m within 1 sec	REF 31
IB3d RECREATIONAL/FISHING	20 m		8 m		REF 31
	HORIZONTAL	**VERTICAL**	**HORIZONTAL**	**VERTICAL**	
IB4 INLAND WATERWAY					REF 31

POSITION ACCURACY - CIVIL					
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**				**SOURCE**
	THRESHOLD		**OBJECTIVE**		
IB4a SAFETY OF NAVIGATION					
IB4a(1) SHIPS & TOWS	5 m within 2 sec		2 m within 1 sec		REF 31
IB4a(2) RECREATION/SMALL VESSELS	10 m within 10 sec		2.5 ft		REF 31
IB4b ENGINEERING & CONSTRUCTION VESSELS	0.1 m within 2 sec	5 m within 2 sec	0.1 m within 1 sec	5 m within 1 sec	REF 31
IB5 PRECISION NAVIGATION	10 cm (2 sigma)	10 cm (2 sigma)			REF 44
IB6 DREDGING	2 m (2 sigma)	5 cm (2 sigma)			REF 44
IB7 MARINE LIFE SCIENCE	5 m (2 sigma)				REF 44
IC AIR	**95% NSE Horizontal**	**95% NSE Vertical**	**95% NSE Horizontal**	**95% NSE Vertical**	
IC1 ENROUTE THROUGH NONPRECISION APPROACH	100 m	N/A	100 m	N/A	FAA
IC2 CATEGORY I (CAT I) PRECISION APPROACH	18.2 m	7.6 m	18.2 m	7.6 m	FAA
IC3 CATEGORY II (CAT II) PRECISION APPROACH	6.5 m	1.7 m	6.5 m	1.7 m	FAA
IC4 CATEGORY III (CAT III) PRECISION APPROACH	3.9 m	0.8 m	3.9 m	0.8 m	FAA
IC5 Airborne Research	TBS				REF 44
II SPACE	**3D Position**	**Attitude**	**3D Position**	**Attitude**	
IIA UP TO GEOSYNCH					
IIA1 GLOBAL TOPOGRAPHIC SURVEY	1 m (1 sigma) (post processed)				NASA/JPL
IIA2 INTERFEROMETRIC SYNTHETIC APERTURE RADAR	0.1 m (1 sigma) (post processed)				NASA/JPL
IIA3 GRAVITY FIELD RECOVERY FROM LEO	0.005 cm (1 sigma) (post processed)				NASA/JPL
IIA4 TOPEX ALTIMETRY MISSION	1 cm (1 sigma) (vertical)				NASA/JPL
IIA5 SATELLITE OPERATIONS (Near Real-time)	6 m	0.1 deg	20 cm	0.01 deg	SATOPS ADT
IIA6 SATELLITE OPERATIONS (Post-processed)	1 cm (w/in 72 hrs)	0.001 deg (w/in 72 hrs)	1 cm (w/in 1 hr)	0.001 deg (w/in 1 hr)	SATOPS ADT
IIB GEO AND BEYOND (Earth Orbiting)					
IIB1 SATELLITE OPERATIONS (Near real-time)	25 m	0.1 deg	10 m	0.01 deg	SATOPS ADT
IIB2 SATELLITE OPERATIONS (Post-processed)	TBD	TBD	TBD	TBD	SATOPS ADT

VELOCITY ACCURACY - MILITARY					
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**				**SOURCE**
	THRESHOLD		**OBJECTIVE**		
I. EARTH AND ATMOSPHERE					
IA LAND	**SPEED**	**DIRECTION**	**SPEED**	**DIRECTION**	
IA1 SURFACE	0.1 m/sec		0.02 m/sec		REF 35
IA1e ARMY LAND		Direction (Mils-LEP)			
IA1e(1) CHEMICAL		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
(2) ENGINEER		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
(2)(a) MINE NEUTRAL		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
(2)(b) MINE DISPENSING		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
(2)(c) GAP CROSSING		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e(3) FIELD ARTILLERY		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
(3)(a) MLRS		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
(3)(b) HOWITZER (TOWED)		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
(3)(c) HOWITZER (SELF-PROPELLED)		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
(3)(d) MORTARS		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
(3)(e) FIST-V		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
(3)(f) FORWARD OBSERVER		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
(3)(g) ARTILLERY RADAR		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
(4)(h) MORTAR LOCATING FIREFINDER RADAR		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e(4) INFANTRY		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e(5) MISSILE MUNITIONS		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e (6) SIGNAL		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e(7) TRANSPORATION (WHEELED VEHICLE)		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e(8) SOLDIER SUPPORT		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e(9) ARMOR		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e(10) MILITARY POLICE		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e(11) SPECIAL OPS FORCES		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e(12) INTELLIGENCE ELECTRONIC WARFARE		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e(13) QUARTERMASTER		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e(14) ORDINANCE		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e(15) AIR DEFENSE ARTILLERY					
IA1e(15)(a) PATRIOT		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IA1e(16)(b) HAWK		1.16 mils (0.4 mils-LEP)		.29 mils (0.10 mils-LEP)	REF 35
IB MARINE					

VELOCITY ACCURACY - MILITARY					
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**				**SOURCE**
	THRESHOLD		**OBJECTIVE**		
IB1 NAVY	**Speed (Km/Hr-LEP)**	**HEADING (DEG-LEP)**	**Speed (Km/Hr-LEP)**	**HEADING (DEG-LEP)**	
IB1a ENROUTE NAVIGATION					
IB1a(1) PILOTAGE WATERS		0.8			REF 39
(2) COASTAL WATERS		0.8			REF 39
(3) INLAND WATERS		0.8			REF 39
(4) OPEN WATERS		0.8			REF 39
(5) RENDEVOUS		0.8			REF 39
IB1b MINE WARFARE	0.2 m/sec (2 sigma)				REF 4
IB1c SPECIAL WARFARE					
IB1c(1) PARADROP	1.85	1			REF 39
(2) SMALL CRAFT	0.93	1			REF 39
(3) COMBAT SWIMMING					
IB1c(3)(a) ENROUTE	0.24	0.5			REF 39
(b) RENDEVOUS	0.24	0.5			REF 39
IB1c(4) LAND WARFARE					
IB1c(4)(a) ENROUTE	0.12	1			REF 39
IB1c(4)(b) RENDEVOUS	0.12	1			REF 39
IB1c(5) INSERTION	0.12	1			REF 39
IB1c(6) EXTRACTION	0.12	1			REF 39
IB1g GEOPHYSICAL SURVEYS					
IB1g(1) DEEP OCEAN AREAS	0.05	0.03			REF 39
IC AIR					
IC1 DOD AVIATION	**Velocity (Km/Hr-LEP)**				
IC1a ENROUTE					
IC1a(1) AIRWAY					
IC1a(1)(a) LOW LEVEL	0.1				REF 39
IC1b APPROACH/LANDING					
IC1b(2) PRECISION					
IC1b(2)(b) SEA	0.9				REF 39
IC1d AMPHIBIOUS WARFARE					
IC1d(1) TRANSPORT	3.7				REF 39
IC1d(2) ATTACK	3.7				REF 39
IC1e ANTISUBMARINE. ANTISURFACE WARFARE	3.7				REF 39
IC1f ANTIAIR WARFARE	5.0				REF 39
	Velocity (Km/Hr-LEP)				
IC1g STRATEGIC BOMBING					

VELOCITY ACCURACY - MILITARY					
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**				**SOURCE**
	THRESHOLD		**OBJECTIVE**		
IC1g(1) CONVENTIONAL	0.10				REF 39
IC1g(2) NUCLEAR	0.10				REF 39
IC1h CLOSE AIR SUPPORT/ INTERDICTION	0.10				REF 39
IC1i ELECTRONIC WARFARE	0.30				REF 39
IC1j C3	0.10				REF 39
IC1m AIR REFUELING	0.10				REF 39
IC1n MINE WARFARE					
IC1n(1) COUNTERMEASURES	3.70				REF 39
IC1n(2) MINE LAYING	3.70				REF 39
IC1oRECONNAISSANCE	0.03				REF 39
IC1p MAGNETIC SURVEY	0.10 m/SEC				REF 39
IC1q GRAVITY SURVEY	0.10 m/SEC				REF 39
IC1r PRECISION GUIDED MISSILES	0.2 m/sec (2 sigma)				REF 4
	m/sec		**m/sec**		
II SPACE	0.001 m/sec		< 0.0001 m/sec		SATOPS ADT
IIA UP TO GEOSYNCH					
IIB GEO AND BEYOND (Earth Orbiting)					

VELOCITY ACCURACY - CIVIL					
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**				**SOURCE**
	THRESHOLD		**OBJECTIVE**		
I. EARTH AND ATMOSPHERE					
IA LAND	**SPEED**	**DIRECTION**	**SPEED**	**DIRECTION**	
IA1 SURFACE	0.4 m/sec (real-time)				REF 44
IB MARINE					
IB1a Marine Life Sciences	0.05 m/sec				REF 44
IC AIR	2 m/s		2 m/s		FAA
II SPACE					
IIA UP TO GEOSYNCH					
IIA1 GPS/MET:UPPER ATMOSPHERE TEMPERATURE PROFILE RECIVERY	.001 m / sec (post-Processed)				NASA/JPL
IIA2 BISTATIC RADAR	0.0001 m / sec (real time)				NASA/JPL
IIA3 SATELLITE OPERATIONS	0.001 m/sec		< 0.0001 m/sec		SATOPS ADT
IIB GEO AND BEYOND (Earth Orbiting)					
IiB1 SATELLITE OPERATIONS	0.001 m/sec		< 0.0001 m/sec		SATOPS ADT

INTEGRITY - MILITARY			
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**		**SOURCE**
	THRESHOLD	**OBJECTIVE**	
I. EARTH AND ATMOSPHERE			
IA LAND			
IA1 SURFACE			
IA2 SUBTERRANEAN			
IB MARINE			
IC AIR	**time(sec) / probability**		
IC1 EN ROUTE			
IC1a AIRWAY			
(1) HMI	10^{-7} per approach		REF 4
(2) Alarm Limit	556 m		REF 4
(3) Time to Alarm	10 sec		REF4
IC1b OCEANIC			
(1) HMI	10^{-7} per approach		REF 4
(2) Alarm Limit	556 m		REF 4
(3) Time to Alarm	10 sec		REF4
IC1c LOW LEVEL	10 / .999		REF 39
IC1d RNAV	30 / .999		REF 39
IC1e TERMINAL	10 / .999		REF 39
IC2 APPROACH/LANDING			
IC2a NONPRECISION			
IC2a(1) LAND			
(i) HMI	10^{-7} per approach		REF 4
(ii) Alarm Limit	556 m		REF 4
(iii) Time to Alarm	10 sec		REF4
IC2a(2) SEA			
(i) HMI	10^{-7} per approach		REF 4
(ii) Alarm Limit	556 m		REF 4
(iii) Time to Alarm	10 sec		REF4
IC2b PRECISION			
IC2b(1) LAND			
(i) HMI	$4x10^{-8}$ per approach		REF 4
(ii) Alarm Limit	4.5 m		REF 4
(iii) Time to Alarm	2 sec		REF4
IC2b(2) SEA			
(i) HMI	$1x10^{-7}$ per approach		REF 4
(ii) Alarm Limit	1.1 m		REF 4
(iii) Time to Alarm	1 sec		REF4

INTEGRITY - MILITARY			
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**		**SOURCE**
	THRESHOLD	**OBJECTIVE**	
IC2c UNPREPARED SURFACE	6 / .999		REF 39
II SPACE	Monitor 24 hr/day up to geosynchronous altitude, 100% monitoring below 10,000 km altitude Time to alarm 6 sec	Monitor 24 hr/day up to geosynchronous altitude Time to alarm 3 sec	SATOPS ADT
IIA UP TO GEOSYNCH			
IIB GEO AND BEYOND (Earth Orbiting)			
IIIA SYSTEM MONITORING	24 hours/day globally		REF 12
IIIB STATUS UPDATE	< 60 sec		

INTEGRITY - CIVIL			
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**		**SOURCE**
	THRESHOLD	**OBJECTIVE**	
I. EARTH AND ATMOSPHERE			
IA LAND			
IA1 SURFACE	10 sec to alarm	5 sec to alarm	REF 44
IB MARINE	10 sec to alarm		REF 44
IC AIR			
IC1 ENROUTE THROUGH NON-PRECISION APPROACH	$1\text{-}10^{-5}$/hour	$1\text{-}10^{-5}$/hour	FAA
IC1a TIME TO ALERT	10 seconds	10 seconds	FAA
IC2 CATEGORY I PRECISION APPROACH	$1\text{-}3.5 \times 10^{-7}$ per approach	$1\text{-}3.5 \times 10^{-7}$ per approach	FAA
IC2a TIME TO ALERT I	6 seconds	6 seconds	FAA
IC3 CATEGORY II PRECISION APPROACH	$1 - 2.5 \times 10^{-9}$ per approach	$1 - 2.5 \times 10^{-9}$ per approach	FAA
IC3a TIME TO ALERT	1 second	1 second	FAA
IC4 CATEGORY III PRECISION APPROACH	$1 - 2 \times 10^{-9}$ per approach	$1 - 2 \times 10^{-9}$ per approach	FAA
IC4a TIME TO ALERT	1 second	1 second	FAA
II SPACE	Monitor 24 hr/day up to geosynchronous altitude, 100% monitoring below 10,000 km altitude Time to alarm 6 sec	Monitor 24 hr/day up to geosynchronous altitude Time to alarm 3 sec	SATOPS ADT
IIA UP TO GEOSYNCH			
IIB GEO AND BEYOND (Earth Orbiting)			

AVAILABILITY - MILITARY			
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**		**SOURCE**
	THRESHOLD	**OBJECTIVE**	
I. EARTH AND ATMOSPHERE			
IA LAND			
IA1 SURFACE			
IA1e ARMY			
IA1e(1) CHEMICAL			
IA1e(1) ENGINEER			
IA1e(1)(a) MINE NEUTRAL			
IA1e(1)(b) MINE DISPENSING			
IA1e(1)(c)			
IA2 SUBTERRANEAN			
IB MARINE			
IC AIR			
IC1 EN ROUTE			
IC1a AIRWAY	99.999%		REF 4
IC1b OCEANIC	99.999%		REF 4
IC2 APPROACH/LANDING			
IC2b PRECISION			
IC2b(1) LAND			
(i) SINGLE RUNWAY	99.8%	99.9%	REF 4
(ii) MULTIPLE AIRPORTS	99.99%	99.999%	REF 4
IC2B(2) SEA	99.8%		REF 4
II SPACE	100% over 24 hours	100% over 24 hours	SATOPS ADT
IIA UP TO GEOSYNCH			
IIB GEO AND BEYOND (Earth Orbiting)			
SERVICE AVAILABILITY	98%, OVER 24 HOUR PERIOD	100% OVER 24 HOUR PERIOD	REF 12
SERVICE RELIABILITY	98%	99.79%	REF 12

AVAILABILITY - CIVIL			
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**		**SOURCE**
	THRESHOLD	**OBJECTIVE**	
I. EARTH AND ATMOSPHERE			
A LAND			
IA1 SURFACE	100% over 24 hours		Ref 44
IA2 SUBTERRANEAN			
IB MARINE	99.9%		
IB1 Ocean			
IB1a ALL CRAFT	99% fix at least every 12 hours		Ref 31
IB1b LARGE SHIPS	99%		Ref 31
IB1c RESOURCE EXPLORATION	99%		Ref 31
IB1d SEARCH OPERATIONS	99%		Ref 31
IB2 COASTAL			
IB2a ALL SHIPS	99.7%		Ref 31
IB2b RECREATION BOATS/SMALL VESSELS	99%		Ref 31
IB2c COMMERCIAL FISHING	99%		Ref 31
IB2d RESOURCE EXPLORATION	99%		Ref 31
IB2e SEARCH OPERATIONS, LAW ENFORCEMENT	99.7%		Ref 31
IB2f RECREATIONAL SPORTS FISHING	99%		Ref 31
IB3 HARBOR ENTRANCE/ APPROACH			
IB3a LARGE SHIPS AND TOWS	99.7%		Ref 31
IB3b SMALLER SHIPS	99.9%		Ref 31
IB3c RESOURCE EXPLORATION	99%		Ref 31
IB3d ENGINEERING & CONSTRUCTION VESSELS	99%		Ref 31
IB3e FISHING, RECREATION, OTHER SMALL VESSELS	99.7%		Ref 31
IB4 INLAND WATERWAY			
IB4a ALL SHIPS AND TOWS	99.9%		Ref 31
IB4b RECREATION BOATS/SMALLER VESSELS	99%		Ref 31
IC AIR			
IC1 ENROUTE THROUGH NON-PRECISION APPROACH	99.999% (3-dimensional), Mask angle 5 degrees above horizon	99.999% (3-dimensional), Mask angle 5 degrees above horizon	FAA
IC2 CATEGORY I PRECISION APPROACH	99.9% (3-dimensional), Mask angle 5 degrees above horizon	99.9% (3-dimensional), Mask angle 5 degrees above horizon	FAA
IC3 CATEGORY II PRECISION	99.9% (3-dimensional), Mask angle 5 degrees above horizon	99.9% (3-dimensional), Mask angle 5 degrees above horizon	FAA

AVAILABILITY - CIVIL			
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**		**SOURCE**
	THRESHOLD	**OBJECTIVE**	
APPROACH			
IC4 CATEGORY III PRECISION APPROACH	99.9% (3-dimensional), Mask angle 5 degrees above horizon	99.9% (3-dimensional), Mask angle 5 degrees above horizon	FAA
II SPACE	100% over 24 hrs	100% over 24 hrs	SATOPS ADT
IIA UP TO GEOSYNCH			
IIB GEO AND BEYOND (Earth Orbiting)			
III PVT SYSTEM			
IIIA SERVICE AVAILABILITY	98 %	99.999 %	Ref 12
IIIB SERVICE RELIABILITY	98 %	99.97 %	Ref 12

TIMING ACCURACY - MILITARY			
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**		**SOURCE**
	THRESHOLD	**OBJECTIVE**	
I. EARTH AND ATMOSPHERE			
IA LAND			
IA1 SURFACE			
IA1a COMMUNICATIONS SITES	1 MICROSECOND ACCURACY TO UTC (USNO)		REF 39
IA1b RADAR SITES	< 1 MICROSECOND ACCURACY TO UTC (USNO)		REF 39
IA1c ECCM COMM, RADAR AND SURVEILLANCE SYSTEMS	10 nanosec to 5 MICROSEC ACCURACY TO UTC (USNO)		REF 39
IA1e ARMY LAND	100 nsec	10 nsec	Army CCSD-OP
IA2 SUBTERRANEAN			
IB MARINE			
IB1 NAVY	TIME/TIME INTERVAL (SEC-1 SIGMA)		
IB1a ENROUTE NAVIGATION			
IB1a(3) INLAND WATERS	0.025		REF 39
IB1b MINE WARFARE	< 10 nsec		REF 4
IB1c SPECIAL WARFARE			
IB1c(1) PARADROP	10		REF 39
(2) SMALL CRAFT	30		REF 39
(3) COMBAT SWIMMING			
(3)(a) ENROUTE	30		REF 39
(3)(b) RENDEVOUS			
(4) LAND WARFARE			
(4)(a) ENROUTE	10		REF 39
(4)(B) RENDEVOUS	10		REF 39
(5) INSERTION	10		REF 39
(6) EXTRACTION	10		REF 39
IB1f HYDROGRAPHIC/ OCEANOGRAPHIC SURVEYS			
IB1f(1) HYDROGRAPHIC SURVEY	20		REF 39
IC AIR			
IC1 PRECISION GUIDED MISSILES	< 10 nsec		REF 4
IC2 LOW ACCURACY AIRCRAFT	1 MILLISECOND ACCURACY TO UTC (USNO)		
II SPACE			
IIA PPS TIME TRANSFER OF UTC (USNO)	20 nsec	1 nsec	REF 12
IIB Satellite Operations	25 nsec	0.01 nsec (post-processed)	SATOPS ADT

TIMING ACCURACY - CIVIL			
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**		**SOURCE**
	THRESHOLD	**OBJECTIVE**	
I. EARTH AND ATMOSPHERE			
IA LAND			
IA1 SURFACE	10 ns	1 nsec	REF 44
IA1a POWER GRIDS	1 microsecond		REF 44
IA1b UTC TO USNO TIME DIFFERENTIAL	10 nsec		REF 44
IB MARINE			
IC AIR			
IC1 ADS * COMMUNICATIONS USING TDMA	5 msec	5 msec	FAA
II SPACE			
IIA SPS TIME TRANSFER FROM UTC	340 nsec (95%)	340 nsec (95%)	Ref 12
IIB HYDROGEN MASER IN SPACE	1 nsec		NASA/JPL
IIC MEASURE MASER STABILITY	0.1 nsec (1 sigma)		NASA/JPL
IID Satellite Operations	25 nsec	0.01 nsec (post-processed)	SATOPS ADT

* ADS = Automatic Dependent Surveillance

COVERAGE - MILITARY			
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**		**SOURCE**
	THRESHOLD	**OBJECTIVE**	
I. EARTH AND ATMOSPHERE			
IA LAND			
IA1 SURFACE	100% when unobstructed by natural or man-made structure		REF 12
IA2 SUBTERRANEAN	TBD		
IB MARINE	Worldwide through all operating environments		REF 12
IC AIR	Worldwide through all operating environments		REF 12
II SPACE	Worldwide to geostationary altitude	Worldwide to twice geostationary altitude (supporting highly elliptical orbit satellites)	SATOPS ADT
IIA UP TO GEOSYNCH			
IIB GEO AND BEYOND (Earth Orbiting)			

COVERAGE - CIVIL			
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**		**SOURCE**
I. EARTH AND ATMOSPHERE	**THRESHOLD**	**OBJECTIVE**	
IA LAND			
IA1 SURFACE	Worldwide through all operating environments		REF 44
IA2 SUBTERRANEAN			
IB MARINE	Worldwide through all operating environments		REF 44
IC AIR	Global (per availability and continuity of service requirements)	Global (per availability and continuity of service requirements)	FAA
II SPACE	Worldwide to geostationary altitude	Worldwide to twice geostationary altitude (supporting highly elliptical orbit satellites)	SATOPS ADT
IIA UP TO GEOSYNCH			
IIB GEO AND BEYOND (Earth Orbiting)			

CONTINUITY OF SERVICE - MILITARY			
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**		**SOURCE**
	THRESHOLD	**OBJECTIVE**	
I. EARTH AND ATMOSPHERE			
IA LAND			
IA1 SURFACE			
IA2 SUBTERRANEAN			
IB MARINE			
IC AIR			
IC1 EN ROUTE			
IC1a AIRWAY			
Multiple Craft > 200 nm	10^{-8} / hr		REF 4
Multiple Craft < 200 nm	10^{-6} / hr		REF 4
Single Craft	10^{-4}		REF 4
IC1b OCEANIC			
Multiple Craft > 200 nm	10^{-8} / hr		REF 4
Multiple Craft < 200 nm	10^{-6} / hr		REF 4
Single Craft	10^{-4}		REF 4
IC2 APPROACH/LANDING			
IC2a NONPRECISION			
IC2a(1) LAND			
Multiple Craft > 200 nm	10^{-8} / hr		REF 4
Multiple Craft < 200 nm	10^{-6} / hr		REF 4
Single Craft	10^{-4}		REF 4
IC2a(2) SEA			
Multiple Craft > 200 nm	10^{-8} / hr		REF 4
Multiple Craft < 200 nm	10^{-6} / hr		REF 4
Single Craft	10^{-4}		REF 4
IC2b PRECISION			
IC2b(1) LAND	$<2X10^{-5}$ per approach		REF 4
IC2b(2) SEA			
(a) Air Capable Ship	$2X10^{-5}$ per approach		REF 4
(b) Last 12 seconds	HMI rate		REF 4
II SPACE			
IIA UP TO GEOSYNCH			
IIB GEO AND BEYOND (Earth Orbiting)			

CONTINUITY OF SERVICE - CIVIL			
OPERATIONAL ENVIRONMENT/ MISSION	**REQUIREMENTS**		**SOURCE**
	THRESHOLD	**OBJECTIVE**	
I. EARTH AND ATMOSPHERE			
IA LAND			
IA1 SURFACE			
IA2 SUBTERRANEAN			
IB MARINE			
IC AIR			
IC1 ENROUTE THRU NON PRECISION APPROACH	$1 - 10^{-4}$ per hour	$1 - 10^{-4}$ per hour	FAA
IC2 CAT I PRECISION APPROACH	$1 - 10^{-5}$ (in any 15 second time period)	$1 - 10^{-5}$ (in any 15 second time period)	FAA
IC3 CAT II PRECISION APPROACH	$1 - 8 \times 10^{-6}$ (in any 15 second time period)	$1 - 8 \times 10^{-6}$ (in any 15 second time period)	FAA
IC4 CAT III PRECISION APPROACH	$1 - 6 \times 10^{-6}$ (in any 30 second time period)	$1 - 6 \times 10^{-6}$ (in any 30 second time period)	FAA
II SPACE			
IIA UP TO GEOSYNCH			
IIB GEO AND BEYOND (Earth Orbiting)			

APPENDIX B

ACRONYMS AND ABBREVIATIONS

DRAFT

Appendix B

ACRONYMS and ABBREVIATIONS

14^{th} AF	Fourteenth Air Force
3-d	three dimensions
A_o	Operational Availability
Acq	Acquisition
ADT	Architecture Development Team
AFSCN	Air Force Satellite Control Network
AFSPC	Air Force Space Command
AJ	Antijam
AIS	Automated Information Systems
AMP	Acquisition Master Plan
AOR	Area of Responsibility
Arch	Architecture
ASAT	Anti-Satellite
ATC	Air Traffic Control
BDA	Battle Damage Assessment
C/A	Coarse Acquisition
C-SCAN	Carrier System for Controlled Approach of Naval Aircraft
C2	Command and Control
C4I	Command, Control, Communications, Computers, and Intelligence
CJCS	Chairman, Joint Chiefs of Staff
CJCSI	Chairman, Joint Chiefs of Staff Instruction
cm	Centimeter
CONOPS	Concept of Operations
CONUS	Continental United States
COS	Continuity of Service
CRD	Capstone Requirements Document
D_o	Operational Dependability
DGPS	Differential Global Positioning System
DIA	Defense Intelligence Agency
DME	Distance Measuring Equipment
DOC	Department of Commerce
DoD	Department of Defense
DOT	Department of Transportation
DPG	Defense Planning Guidance
DPS	

DRMS	Distance Root Mean Square
DSMAC	Digital Scene Matching Area Correlation
EGNOS	European Geostationary Navigation Overlay Service
el	Elevation
EMP	Electromagnetic Pulse
EPA	Environmental Protection Agency
EW	Electronic Warfare
FAA	Federal Aviation Administration
FDE	Fault Detection and Exclusion
FL	Flight Level
FRP	Federal Radionavigation Plan
FOC	Full Operational Capability
FY	Fiscal Year
GA	Ground Antenna
GANS	Global Access, Navigation, and Safety
GATM	Global Air Traffic Management
GCA	Ground Controlled Approach
GCCS	Global Command and Control System
GCSS	Global Command Support System
GIS	Geographic Information System
GEO	Geosynchronous Earth Orbit
GLONASS	Global Navigation Satellite System
GPS	Global Positioning System
GZ	Ground Zero
HEO	Highly Elliptical Orbit
HMI	Hazardously Misleading Information
ICAO	International Civil Air Organization
IGEB	Interagency GPS Executive Board
ILS	Instrument Landing System
IMO	International Maritime Organization
INS	Inertial Navigation System
ISS	International Space Station
IVHS	Intelligent Vehicle Highway System
IW	Information Warfare
JCAB	Japan Civil Aviation Bureau
JPALS	Joint Precision Approach and Landing System
JPL	Jet Propulsion Laboratory
JROC	Joint Requirements Oversight Council
JTIDS	Joint Tactical Information Distribution System

Km	Kilometer
KPP	Key Performance Parameter
LAAS	Local Area Augmentation System
LEO	Low Earth Orbit
LORAN	Long Range Navigation
m	Meter
mm	Millimeter
MAP	Mission Area Plan
MATCALS	Marine Air Traffic Control and Landing System
Mgt	Management
MHz	Megahertz
MIJI	Meaconing, Interference, Jamming, and Intrusion
MLS	Microwave Landing System
MNP	Master Navigation Plan
MNS	Mission Need Statement
MRAALS	Marine Remote Area Approach and Landing System
MTSAT	Multi-function Transport Satellite
MTW	Major Theater War
NAIC	National Air Intelligence Center
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NAVAIDS	Navigation Aids
NDB	Nondirectional Beacons
NIPRNET	Non-Secure Internet Protocol Router Network
NM	Nautical Mile
NRT	Near-Real-Time
nsec	Nanosecond
NSTC	National Science and Technology Council
NUDET	Nuclear Detection
Obj	Objective
Ops	Operations
ORD	Operational Requirements Document
OTH	Over-the-Horizon
PADS	Position Azimuth Determining System
PALS	Precision Approach Landing System
PAR	Precision Approach Radar
PDD	Presidential Decision Directive
POM	Program Objective Memorandum
POS/NAV	Positioning and Navigation

PP	Post Processing
PPBS	Planning, Programming, and Budgeting System
PPS	Precise Positioning System
PVT	Positioning, Velocity, and Time
RAIM	Receiver Autonomous Integrity Monitoring
RF	Radio Frequency
RNP	Required Navigation Performance
Rqmts	Requirements
RTK	Real-Time Kinematics
SA	Selective Availability
SATNAV	Satellite Navigation
SATOPS	Satellite Operations
sec	Second
SEP	Spherical Error Probable
SIAGL	Survey Instrument Azimuth Gyroscope Lightweight
SIGINT	Signals Intelligence
SIPRNET	Secure Internet Protocol Router Network
SIS	Signals in Space
SMC	Space and Missile Systems Center
SPS	Standard Positioning Service
SRP/PDS	Stabilization Reference Package/Position Determining System
SSC	Small Scale Contingency
STAR	System Threat Assessment Report
SV	Space Vehicle
TACAN	Tactical Air Navigation
TBP	To Be Provided
TERCOM	Terrain Contour Matching
TOPEX/POSEIDON	TOPographic EXperiment/POSEIDON
UE	User Equipment
US	United States
USAF	United States Air Force
USC	United States Code
USCG	United States Coast Guard
USG	US Government
USNO	United States Naval Observatory
USSPACECOM	United States Space Command
UTC	Coordinated Universal Time
UTC (USNO)	UTC as maintained at the USNO

VHF	Very High Frequency
VOR/DME	Very High Frequency Omnidirectional Range/Distance Measuring Equipment
VTS	Vessel Traffic Service
WAAS	Wide Area Augmentation System
WGS	World Geodetic Survey

APPENDIX C

GLOSSARY

Appendix C

GLOSSARY

Air Traffic Control (ATC) - A service operated by appropriate authority to promote the safe, orderly, and expeditious flow of air traffic.

Approach Reference Datum - A point at a specified height above the runway centerline and the threshold. The height of the MLS approach reference datum is 15 meters (50 ft). A tolerance of plus 3 meters (10 ft) is permitted.

Area Navigation (RNAV) - Application of the navigation process providing the capability to establish and maintain a flight path on any arbitrarily chosen course that remains within the coverage area of navigation sources being used.

Automatic Dependent Surveillance - A function in which aircraft automatically transmit navigation data derived from onboard navigation systems via a datalink for use by air traffic control.

Block II/IIA - The satellites that form the initial GPS constellation at FOC.

Cellular Triangulation - A method of location determination using the cellular phone system where the control channel signals from a mobile phone are captured by two or more fixed base stations and processed according to an algorithm to determine the location of the mobile receiver.

Circular Error Probable (CEP) - In a circular normal distribution (the magnitudes of the two one-dimensional input errors are equal and the angle of cut is 90 o), circular error probable is the radius of the circle containing 50 percent of the individual measurements being made, or the radius of the circle inside of which there is a 50 percent probability of being located.

Coastal Confluence Zone (CCZ) - Harbor entrance to 50 nautical miles offshore or the edge of the continental shelf (100 fathom curve), whichever is greater.

Common-use Systems - Systems used by both civil and military sectors.

Conterminous US - Forty-eight adjoining states and the District of Columbia.

Coordinate Conversion - The act of changing the coordinate values from one system to another; e.g., from geodetic coordinates (latitude and longitude) to Universal Transverse Mercator grid coordinates.

Coordinated Universal Time (UTC) - UTC, an atomic time scale, is the basis for civil and DoD time. It is occasionally adjusted by one-second increments to ensure that the difference between the uniform time scale, defined by atomic clocks, does not differ from the earth's rotation by more than 0.9 seconds. UTC (USNO) is the real-time realization of UTC for the purpose of UTC dissemination by the GPS.

Differential - A technique used to improve radionavigation system accuracy by determining positioning error at a known location and subsequently transmitting the determined error, or corrective factors, to users of the same radionavigation system, operating in the same area.

Distance Root Mean Square (drms) - The root-mean-square value of the distances from the true location point of the position fixes in a collection of measurements. As used in this document, 2 drms is the radius of a circle that contains at least 95 percent of all possible fixes that can be obtained with a system at any one place. Actually, the percentage of fixes contained within 2 drms varies between approximately 95.5 percent and 98.2 percent, depending on the degree of ellipticity of the error distribution.

En Route - A phase of navigation covering operations between a point of departure and termination of a mission. For airborne missions the en route phase of navigation has two subcategories, en route domestic and en route oceanic.

En Route Domestic - The phase of flight between departure and arrival terminal phases, with departure and arrival points within the conterminous United States.

En Route Oceanic - The phase of flight between the departure and arrival terminal phases, with an extended flight path over an ocean.

Flight Technical Error (FTE) - The contribution of the pilot in using the presented information to control aircraft position.

Full Operational Capability (FOC) - For GPS, this is defined as the capability that will occur when 24 operational (Block II/IIA) satellites are operating in their assigned orbits and have been tested for military functionality and meet military requirements.

Geocentric - Relative to the Earth as a center, measured from the center of mass of the Earth.

Geodesy - The science related to the determination of the size and shape of the Earth (geoid) by such direct measurements as triangulation, leveling, and gravimetric observations; which determines the external gravitational field of the Earth and, to a limited degree, the internal structure.

Geometric Dilution Of Precision (GDOP) - All geometric factors that degrade the accuracy of position fixes derived from externally-referenced navigation systems.

Inclination - One of the orbital elements (parameters) that specifies the orientation of an orbit. Inclination is the angle between the orbital plane and a reference plane, the plane of the celestial equator for geocentric orbits and the ecliptic for heliocentric orbits.

Initial Operational Capability (IOC) - For GPS, this is defined as the capability that will occur when 24 GPS satellites (Block I/II/IIA) are operating in their assigned orbits and are available for navigation use.

Multipath Transmission - The propagation phenomenon that results in signals reaching the receiving antenna by two or more paths. When two or more signals arrive simultaneously, wave interference results. The received signal fades if the wave interference is time varying or if one of the terminals is in motion.

Meaconing - A technique of manipulating radio frequency signals to provide false navigation information.

Nanosecond (ns) - One billionth of a second.

National Airspace System (NAS) - The NAS includes US airspace; air navigation facilities, equipment and services; airports or landing areas; aeronautical charts, information and service; rules, regulations and procedures; technical information; and labor and material used to control and/or manage flight activities in airspace under the jurisdiction of the US System components shared jointly with the military are included.

National Command Authority (NCA) - The NCA is the President or the Secretary of Defense, with the approval of the President. The term NCA is used to signify constitutional authority to direct the Armed Forces in their execution of military action. Both movement of troops and execution of military action must be directed by the NCA; by law, no one else in the chain of command has the authority to take such action.

Nautical Mile (nm) - A unit of distance used principally in navigation. The International Nautical Mile is 1,852 meters long.

Navigation - The process of planning, recording, and controlling the movement of a craft or vehicle from one place to another.

Nonprecision Approach - A standard instrument approach procedure in which no electronic glide slope is provided (e.g., VOR, TACAN, Loran-C, or NDB).

Primary Means of Navigation - Identifies navigation equipment which provides the only required means on an aircraft of satisfying the necessary level of accuracy, integrity, and availability for a particular area, route, procedure, or operation. The failure of a primary means of navigation requires reversion to a non-normal means of navigation (e.g., dead reckoning).

Precise Time - A time not to exceed a range which is defined by user requirements.

Precision Approach - A standard instrument approach procedure using a ground-based system in which an electronic glide slope is provided (e.g., ILS).

Primary-means Navigation System - Meets accuracy and integrity requirements, but does not meet full availability and continuity requirements.

Pseudolite - Ground-based transmitters that can be configured to emit GPS-like signals for enhancing the GPS by providing increased accuracy, integrity, and availability.

Radiodetermination - The determination of position, or the obtaining of information relating to positions, by means of the propagation properties of radio waves.

Radiolocation - Radiodetermination used for purposes other than those of radionavigation.

Radionavigation - The determination of position, or the obtaining of information relating to position, for the purposes of navigation by means of the propagation properties of radio waves.

Receiver Autonomous Integrity Monitoring (RAIM) - A technique whereby a civil GPS receiver/processor determines the integrity of the GPS navigation signals without reference to sensors or non-DoD integrity systems other than the receiver itself. This determination is achieved by a consistency check among redundant pseudorange measurements.

Reliability - The probability of performing a specified function without failure under given conditions for a specified period of time.

Required Navigation Performance - A statement of the navigation performance accuracy necessary for operation within a defined airspace, including the operating parameters of the navigation systems used within that airspace.

RHO (Ranging Mode) - A mode of operation of a radionavigation system in which the times for the radio signals to travel from each transmitting station to the receiver are measured rather than their differences (as in the hyperbolic mode).

Roadside Beacons - A system using infrared or radio waves to communicate between transceivers placed at roadsides and the in-vehicle transceivers for navigation and route guidance functions.

Sigma - See Standard Deviation.

Sole-means Navigation System - Meets accuracy, integrity, availability, and continuity requirements.

Spherical Error Probable (SEP) - The radius of a sphere within which there is a 50 percent probability of locating a point or being located. SEP is the three-dimensional analogue of CEP.

Standard Deviation (sigma) - A measure of the dispersion of random errors about the mean value. If a large number of measurements or observations of the same quantity are made, the standard deviation is the square root of the sum of the squares of deviations from the mean value divided by the number of observations less one. Averaged, the standard deviation of their average is less than the standard deviation of any one observation, but can never be less than the systematic errors common to all observations

Supplemental Air Navigation System - An approved navigation system that can be used in controlled airspace of the National Airspace System in conjunction with a primary means of navigation.

Supplemental-means of Navigation - Meets accuracy and integrity requirements for a given phase of flight. Does not meet availability and continuity requirements. Must be used in conjunction with a sole-means system.

Surveillance - The observation of an area or space for the purpose of determining the position and movements of craft or vehicles in that area or space.

Survey - The act of making measurements to determine the relative position of points on, above, or beneath the Earth's surface.

Surveying - That branch of applied mathematics which teaches the art of determining accurately the area of any part of the Earth's surface, the lengths and directions of the bounding lines, the contour of the surface, etc., and accurately delineating the whole on a map or chart for a specified datum.

Terminal - A phase of navigation covering operations required to initiate or terminate a planned mission or function at appropriate facilities. For airborne missions, the terminal phase is used to describe airspace in which approach control service or airport traffic control service is provided.

Terminal Area - A general term used to describe airspace in which approach control service or airport traffic control service is provided.

Theta - Bearing or direction to a fixed point to define a line of position.

Time Interval - The duration of a segment of time without reference to where the time interval begins or ends.

TOPEX/POSEIDON - TOPographic EXperiment/POSEIDON mission, a joint US/French oceanic mapping mission launched in August 1992.

Universal Transverse Mercator (UTM) Grid - A military grid system based on the Transverse Mercator projection applied to maps of the Earth's surface extending to 84 degrees N and 80 degrees S latitudes.

Vehicle Location Monitoring - A service provided to maintain the orderly and safe movement of platforms or vehicles. It encompasses the systematic observation of airspace, surface and subsurface areas by electronic, visual or other means to locate, identify, and control the movement of platforms or vehicles.

World Geodetic System (WGS) - A consistent set of parameters describing the size and shape of the Earth, the positions of a network of points with respect to the center of mass of the Earth, transformations from major geodetic datums, and the potential of the Earth (usually in terms of harmonic coefficients).

APPENDIX D

REFERENCES

Appendix D

REFERENCES

1. CSAF/CV Message, 281504Z January 1997, Subject: Global Positioning System Capstone Requirements Document

2. AF Navigation and Safety Master Plan, 26 Aug 96.

3. Example of an RMA Enabling Technology with Implications, Earl W. Rubright, 27 Mar 97.

4. US Navy Operational Requirements Document for GPS User Equipment, Undated (DRAFT)

5. US Navy MNS for Protection and Prevention of Space-Based Global Navigation Systems, 12 March 96

6. Joint USAF-USN MNS for Precision Approach and Landing Capability, 9 August 1994.

7. Under Secretary of Defense and the Vice Chairman, Joint Chiefs of Staff Memorandum of 6 June 1996.

   Directed actions which are intended to "enable DoD aircraft to take off, fly and recover to non-precision approach minima anywhere in the world without reference to ground-based radionavigation aids."

8. Capstone Requirements Document 001-97, Global Air Traffic Management, HQ AMC/XPQN, (Draft), Revision 1, 12 May 1997

9. AMC MNS 001-92, Data Link Capability, 28 Jun 93

10. Air Force Space Command Mission Need Statement 003-92 for Improved Worldwide Navigational Positioning System, AFSPACECOM/DRFN, 29 January 1993

11. AFSPACECOM (USAF 003-78) I/II/III SORD, Navstar Global Positioning System (GPS), AFSPACECOM/XPSS, 22 Jan 90.

12. Air Force Space Command Operational Requirements Document 003-92-III, Worldwide Navigational Positioning System, HQ AFSPC/DR, 21 March 1997 (Draft).

13. Chairman, Joint Chiefs of Staff Instruction 6130.01, CJCS Master Navigation Plan, 20 May 1994

14. White House Commission on Aviation Safety and Security, Final Report to President Clinton, February 12, 1997

15. Concept of Operations for the NAVSTAR Global Positioning System (GPS), HQ AFSPC/DOXC, June 1996

16. Annex A to the Concept of Operations for Air Force Satellite Control, "Backup Operations," HQ AFSPC/DOXC, Undated

17. Systems Operation Concept Description For The Block IIF NAVSTAR Global Positioning System, prepared for the Space and Missile Systems Center, 1 February 1997 (Draft)

18. Air Force Modernization Planning, Space Information Dominance Mission Area Plan, HQ AFSPC/XPX, 17 December 1996

19. 1994 Federal Radionavigation Plan, Eighth Edition, Department of Defense (USD/A&T) and Department of Transportation (OST/P), May 1995

20. ACC ORD 003-95-I/II, Operational Protection and Prevention of Global Space-Based Navigation Systems Navigation Warfare (NAVWAR), undated (Draft).

21. AMC MNS 004-93, Intraformation Positioning/Collision Avoidance Capability, 23 Nov 93

22. AMC MNS 007-93, Reduced Vertical Separation Minima (RVSM) Capability, 8 Jan 94.

23. A Technical Report to the Secretary of Transportation on a National Approach to Augmented GPS Service, December, 1994.

24. Joint US Department of Defense/US Department of Transportation Task Force, *The Global Positioning System: Management and Operation of a Dual Use System*, Washington, DC, December 1993 (Added)

25. DoD Memorandum to National Academy of Public Administration from DUSD (Space), 10 April 1995, Re: Draft Study on GPS.

26. DoD Memorandum to Dr James Schlesinger from USD (A&T), 22 May 1995, Re: NAPA and NAS GPS Study.

27. Navstar Global Positioning System (GPS), System Threat Assessment Report (STAR) (U), NAIC-1574-0407-97, March 1997

DRAFT

28. The Space Systems Threat Environment Description, (SECRET), dated 11 September 1995, produced by the National Air Intelligence Center (NAIC)

29. Space Information Dominance Mission Area Plan, HQ AFSPC/XPX, 17 December 1996

30. Operational Requirements Document I (ORD) Joint Precision Approach Landing System ACAT Level ID, 15 Oct 96

31. 1996 Federal Radionavigation Plan (draft), Ninth Edition, Department of Defense (USD/A&T) and Department of Transportation (OST/P)

32. Headquarters Air Combat Command ORD for GPS Navigation Warfare User Requirements (Draft), May 1996

33. ESA In Brief, European Space Agency Bulletin Nr. 87, August 1996

34. Global Positioning and Navigation News

35. US Army Signal Center ORD for the GPS Tactical Receiver, 24 Mar 1997

36. FAA ORD for Local Area Augmentation System, Change 1, 7 December 1995

37. Air Mobility Command MNS for Required Navigation Performance (AMC 003-97) (Draft), Undated

38. Department of Defense Directive 4650.5, Positioning and Navigation Systems Administration and Planning, 5 Dec 1990

39. Chairman, Joint Chiefs of Staff Instruction 6130.01, 1997 CJCS Master Navigation Plan, (Draft)

40. USSPACECOM MNS 003-95, Operational Protection and Prevention of Global Space-Based Navigation Systems (U), Sep 95

41. AFSPC Operational Requirements Document for Global Positioning System Jammer, (Draft)

42. Duffet-Smith, P. ``Time." Practical Astronomy with Your Calculator, 3rd ed. Cambridge, England: Cambridge University Press, pp. 1-23, 1992.

43. New World Vistas, Space Applications Volume, Science Advisory Board, December, 1995.
44. DOT Requirements Survey in Support of the PVT CRD, March 1997 and Continuing

45. SMC/CZ GPS Modernization Briefing, 24 June 1997Briefing

46. The “Global Positioning System, Charting the Future” Study. May 1995, published by the National Academy of Public Administration and the National Research Council.

47. Universal Joint Task List, Version 3.0, CJCSM 3500.04A, 13 September, 1996.

48. Joint Vision 2010, Office of the Joint Chiefs of Staff, 1997.
49. The Global Positioning System, A Shared National Asset, National Research Council, 1995
50. DoD Directive 4650.5, Positioning and Navigation Systems Administration and Planning, December 5, 1990
51. Air Combat Command MNS 003-95 for Operational Protection and Prevention of Global Space-based Navigation Systems, 27 Sep 1995

APPENDIX E

OTHER PVT SYSTEMS

DRAFT

Appendix E

OTHER PVT SYSTEMS

This appendix is a supplement to Section 3. It summarizes the capabilities of special-purpose PVT systems that were developed (or are under development) for specific purposes. Their development and fielding is not intended to satisfy the general military and civil need for PVT services documented in Section 4 and Appendix A of this CRD. This appendix is limited to a tabular summary (Table E-1) of system capabilities and characteristics. For more detail on these systems refer to the CJCS Master Navigation Plan and the Federal Radionavigation Plan.

DRAFT

Table E-1. Other PVT Systems

System	Service	Coverage	Accuracy	Availability	Status		Operator
					DoD	Civil	
Air Traffic Control and Landing Systems	Communications, Navigation, Surveillance				HQ USAF MNS 001-96		Military Services
Air Traffic Control Radar Beacon System	Identification, Positioning (Altitude)	LOS (< 250 nm)	± 300 m range ± 1.6-5.6° bearing		Operational		Military Services
Air Traffic Control Radar	Positioning	Dependent on altitude	Range: ± 150 m, Bearing: ± 1.2°		Operational		Military Services
Bottom Contour Navigation	Positioning (from sea bottom)		± 200 m (with accurate charts)		Operational		US Navy
Carrier Systems for Controlled Approach of Naval Aircraft	Positioning	Range: 19 km Azimuth: +20° Elevation: 0-10°	Relative: ± 0.2° azimuth ± 0.1° elevation		Operational		US Navy
Celestial Navigation	Positioning	Global	Average error: 2 nm, 3 - 30 m with automation		Operational	Operational	Military Services, Civil users
Continuously Operating Reference Station	Positioning (post processing)	Nationwide	Precise, relative to NAD 83			75 stations as of Sep 96 (many are dual use)	National Geodetic Survey (DGPS, WAAS, NOAA)
Differential GPS	Positioning, Velocity, Timing	TBD	Similar to WAAS/LAAS		JPALS acquisition		Military Services
Digital Airport Surveillance Radar	Positioning	Primary: 60 nm rad to 24K ft AGL; Secondary: 120 nm to 60K ft AGL	1 sq m taget: Azimuth: 0.16° rms, Range: .125 nm at .80 Pd		Acquisition, joint DoD and FAA	See DoD	Military Services, FAA
Direction Finding	Positioning (Bearing)	Line of sight from transmitter	Relative: ± 3 to 5°	99%	Operational		Millitary Services
Doppler	Positioning, Velocity	Global	0.1 to 0.3%		Operational		Military Services
Digital Scene Matching Area Correlation	Positioning (missile guidance)	Target area			Operational		US Navy
Joint Tactical Information Distribution System	Positioning	Tactical theater	75 m		Operational		Military Services

System	Service	Coverage	Accuracy	Availability	Status		Operator
					DoD	Civil	
Marine Air Traffic and Landing System	Positioning	Azimuth: ± 23° Elevation: -1° to +7°	Azimuth: ± 3 m Elevation:± 2 m (at 1 km)		Operational		US Marine Corps
Marine Remote Area Approach and Landing System	Positioning	Distance: 18.5 km Azimuth: ± 20° Elevation: 0 - 20°	Az: ± 1.74 m El: 0.87 m Range: ± 70 m at 1 km		Operational		US Marine Corps
Maritime Differential GPS	Positioning, Velocity, Timing	US Coasts to 20 nm from shore, Hawaii, coastal Alaska, Puerto Rico, major US rivers	10 meters or less (2 drms)	99.9% in selected waterways and 99.7% in other areas		Operational, Rapidly increasing use	US Coast Guard
Mobile Microwave Landing System				37 mobile sets for contingency operations	Operational		US Air Force
National Institute of Standards and Technology (WWV, WWVH)	Timing	Beyond line of sight of stations, depends on propagation	Within 1 µsec of USNO Master Clock; BLOS is 1 msec (corrected)			Operational - stations at Boulder CO and Hawaii	NIST
North Seeking Gyroscope	Positioning	Worldwide from 0-75° latitude	Az error: 8.5 mils Vertical angle error: 3.5 mils		Operational		US Army
Position Location Reporting System	Positioning	Division tactical area, 100 nm for aircraft	Horz: 25-30 m Vertical error: 3% of platform alt.		Acquisition		US Army US Marine Corps
Precision Approach and Landing System	Positioning	Distance: 15 km Azimuth: ± 55° Elevation: -15 to +30°	Azimuth & elevation: ± 0.044°		Operational		US Navy
Polarfix	Positioning	5 km	± 0.5 m ± 0.1 % of measured dist.		Operational		US Navy, US Army
Position and Azimuth Determining System	Positioning	7 hr or 55 km mission duration	Hor: 4 m CEP Vert: 2 m PE 0.4 mil (PE) directional	Reliability: 500 to 1000 hours MTBF	Operational		US Army
Precision Landing System Receiver	Multi-mode receiver (ILS, MLS, DGPS)				JPALS acquisition		Military Services

DRAFT

System	Service	Coverage	Accuracy	Availability	Status		Operator
					DoD	Civil	
Survey Instrument, Azimuth Gyro, Lightweight	Positioning	Worldwide (from 0 to 75° latitude)	± 0.15 mils divided by cosine of latitude		Operational		US Army
Stabilization Reference Package/ Position Determining System	Positioning (direction, elevation, cant)				Operational		Military Services
Terrain Contour Matching	Positioning	Specifically digitized land areas			Operational		Military Services
Vessel Traffic Services	Positioning	0-24 nm from antenna	Range: ± 20 yds Bearing: ± 1.25°			Operational	US Coast Guard
Other Special-use Systems: Doppler Log, Advanced HF Submarine SONAR, Precise Integrated Navigation System, Modular Position and Azimuth System and MAPS-Hybrid, Improved Instrument Azimuth Gyro Lightweight, Gun-Laying Positioning System, Lightweight Laser Designator Rangefinder, Multiple Launch Rocket System, Integrated Communications, Navigation, and Identification Avionics, Improvements in Precise Time and Time Interval							

APPENDIX F

PVT SYSTEM GRADING RATIONALE

RATIONALE

User requirements referred to are those documented in Section 4 and Appendix A.

GREEN (G) indicates all user requirements of the particular system will be satisfied.

YELLOW (Y) indicates some user requirements will be met, but some will not.

RED (R) indicates no user requirements will be met by the system.

ASSUMPTIONS/CRITERIA: Rating systems that were fielded to meet a specific purpose in a particular environment is, of necessity, subjective. Assumptions and criteria used are stated below.

a. Availability was measured against the basis of the system's ability to provide required PVT information within acceptable limits documented for signal outages.

b. Coverage was based on the system's ability to provide global coverage (a user requirement). For example, GPS LAAS provides service within its operating radius of the LAAS transmitter, but since transmitters are not deployed to cover the globe, it can’t be rated green for coverage.

3. Security ratings were determined by the system's ability or potential ability to operate and provide PVT information in a jamming, spoofing, and exploitation environment, even though a system may not have been designed with security in mind.

4. Affordability was determined by the relative expense of that system compared to others that provide essentially the same service. While a system may indeed be determined to be worth its cost, it may still be considered yellow or red because of the cost relative to similar systems. Additionally, existing systems’ projected funding levels were also included in this analysis. For example, GPS was rated yellow because it has budget disconnects from what is required to fully satisfy mission requirements.

5. Interoperability was judged based on the system's adaptability to provide service to all/many users, despite its originally intended mission. For example, Bottom Contour Navigation may well satisfy the requirements for sub-surface/surface marine users, but it would be very difficult, if not impossible, for that system to support aviation users. Therefore, it received a yellow rating.

F.1 GROUND CONTROLLED APPROACH/PRECISION APPROACH RADAR

This system has coverage problems since a user must be within line of sight and within a specified approach corridor from the end of an airport runway to use these systems. The signals are unencrypted causing security concerns. Maintenance on the transmitters is costly.

F.2 **GLOBAL POSITIONING SYSTEM**

The current stand alone system will not be able to provide the accuracies all users will require in the future, but some users will continue to be satisfied. System security remains to be dealt with through protection and prevention. Characteristics rated as red or yellow will require some kind of augmentation, such as pitot-static, or inertial systems.

F.3 **INSTRUMENT LANDING SYSTEM**

This system is a precision approach and landing system only, and as such, usage and coverage is limited to approach corridors to airport runways. Availability approaches 100%.

F.4 **INERTIAL NAVIGATION SYSTEM**

Since this system is self-contained, security and survivability generally satisfy future requirements. Timing accuracy remains a critical shortfall. Integrity could either be acceptable, in the case of a complete INS failure, or unacceptable, in the case of insidious drift rates.

F.5 **LORAN-C**

This system is scheduled for deactivation, and was considered red “across the board.”

F.6 **MARITIME DIFFERENTIAL GPS**

Since the system is intended for maritime only use, signal availability and coverage were downgraded. With system growth and maturity, these ratings could be upgraded. Interoperability was also a weakness since separate receivers, or at a minimum, upgraded GPS receivers are required. Survivability of the signal is questionable in times of conflict.

F.7 GPS WIDE AREA AUGMENTATION SYSTEM

One of the best current systems to meet future requirements, the issues of security, survivability, and cost are still of concern.

F.8 GPS LOCAL AREA AUGMENTATION SYSTEM

Similar in capability to the Coast Guard's Maritime DGPS system, the limitations for this system are, unsurprisingly, shared as well.

F.9 MARINE AIR TRAFFIC CONTROL & LANDING SYSTEM

This system was developed to satisfy precision traffic control and landing for Navy and USMC aircraft at expeditionary airfields. Provides excellent position accuracy, while velocity and timing accuracies are limited to non-existent. Coverage is obviously limited to those fields broadcasting this signal to arriving aircraft, typically 15 km. Survivability is a concern.

F.10 AIR TRAFFIC CONTROL RADAR

RADARs are limited in accuracy capability, whether position or velocity. Availability and coverage are dependent upon altitude, survivability is suspect given radar homing weapons and anti-radar defenses, and security is questionable given today's anti-radar capabilities. Maintenance costs are high for this system.

F.11 BOTTOM CONTOUR NAVIGATION

Coverage of ocean bottom terrain is limited to areas that have previously been charted. Echo sounder (sonar) is used to determine submarine position comparing readings with bottom terrain features. Accuracy is only about 200m. No timing information is provided.

F.12 CARRIER SYSTEMS FOR CONTROLLED APPROACH OF NAVAL AIRCRAFT

Limited in coverage to the approach end of aircraft carriers, and accessible to naval aviation on approach to landing on those carriers. Similar to ILS. Security is of concern, as is survivability. Users other than naval aircraft would need modification to take advantage of this system. Timing accuracy is not provided.

F.13 CELESTIAL NAVIGATION

Traditionally practiced celestial navigation results in typical position accuracies of 2 nautical miles. Access to navigation information and corrections can be improved by performing calculations electronically, and position accuracies of 3-30 meters can be attained with automated systems such as STELLA—The System To Estimate Latitude and Longitude Astronomically.

F.14 DIFFERENTIAL GPS (DGPS)

This is a reference to the DGPS under study by DoD. Concerns exist over security and survivability of DGPS signals. DGPS can continue to operate while part of the system is down or corrupted. However, some accuracies are jeopardized in the process. The issue of affordability is based on the current development of the system as well as additional hardware that is required for operation and use of signal. The integrity and signal availability are currently under study.

F.15 DIGITAL AIRPORT SURVEILLANCE RADAR

DASR accuracies are good for cruise and general location monitoring, but range errors cause it to become less reliable for close approach situations. In addition, its coverage is limited to the capacity and location of the RADAR installations, and is limited to aircraft usage. RADAR serviceability concerns exist for the long term, and times of disrepair may increase.

F.16 DIRECTION FINDING

Provides good relative accuracies for bearing measurements but positional accuracies are not very good. Coverage limited to line-of-sight from user to the transmitter. Simple UHF transmissions raise security and survivability concerns.

F.17 DOPPLER

Position and velocity accuracies are good. However, they are reliant upon accurate data input into the system to augment the Doppler readings. Additionally, the precision of the information varies with the conditions experienced by the aircraft which leads to integrity faults. While, the Doppler system is capable of being fitted on all aircraft, its coverage is limited to numbers of aircraft fitted with Doppler as well as the flight regimes of the aircraft themselves. Restrictions on flight profiles while using this system may concern some users.

F.18 DIGITAL SCENE MATCHING AREA CORRELATION

This system is a target area missile guidance system. Unlike TERCOM, DSMAC is reliant upon digitized photographs of target area. Without the photographs the system is inoperable. Missile guidance to the target area must be accomplished by other means.

F.19 JOINT TACTICAL INFORMATION DISTRIBUTION SYSTEM

A command and control system, JTIDS has an inherent relative navigation capability that can be programmed to emulate, on a time-shared basis, the performance of a TACAN transponder. Position accuracy is 75 meters, provided a minimum of four platforms in a suitable geometric position. JTIDS is primarily limited to line-of-sight with some exceptions for over-the horizon, so coverage is limited. Availability is limited to those with a JTIDS terminal. Integrity is poor at this time as its reliability has yet to be determined.

F.20 SURVEY INSTRUMENT, AZIMUTH GYRO, LIGHTWEIGHT (SIAGL)

A man portable, north seeking gyro, this system provides good bearing accuracy, but time to initialize and observe is rather high (15 minutes each) which lends itself to security concerns for artillery surveyors, not as much for civil surveyors. Follow-on improvements to this system indicate directional accuracies of .2 mil within 3 minutes after setup. Coverage is limited to 75 degrees latitude.

F.21 STABILIZATION REFERENCE PACKAGE/POSITION DETERMINATION SYSTEM

Used on Multiple Launch Rocket System (MLRS), SRP/PDS provides direction, elevation and cant angles. The system is susceptible to errors in calculations and provides position location using data from two odometers connected to vehicle tracks. and requires periodic updates at control points.

F.22 TERRAIN CONTOUR MATCHING (TERCOM)

Using radar and barometric altimetry to determine a 3-D position by comparing detected terrain profiles with prestored profiles of the terrain being traversed, coverage of TERCOM is limited to land areas that have previously been digitized. All other land regions are unavailable to TERCOM, as will be large bodies of water.

F.23 VESSEL TRAFFIC SERVICES (VTC)

VTC is limited in use. Only eight stations currently available around the US with a limited range around their base harbor. Accuracies generally meet the needs of vessels, however, may be lacking in cases where precise location and velocity information are needed such as transportation of HAZMAT. Each VTC location is self supporting yet not very protected from possible problems. Human operators are always needed for monitoring.