CJCSI 6130.01B
15 June 2000

2000 CJCS MASTER POSITIONING, NAVIGATION, AND TIMING PLAN

JOINT STAFF
WASHINGTON, D.C. 20318-0300

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CHAIRMAN OF THE JOINT CHIEFS OF STAFF INSTRUCTION

J-6 CJCSI 6130.01B
DISTRIBUTION: S 15 June 2000

2000 CJCS MASTER POSITIONING, NAVIGATION, AND TIMING PLAN

References: See Enclosure K.

1. Purpose. This instruction constitutes the DOD's plan for use, sustainment, and modernization of positioning, navigation, and timing (PNT) systems to meet operational requirements. This instruction reflects the policy and directions contained in the referenced documents.

a. This plan implements CJCS joint systems responsibilities. It provides the policy and planning bases for DOD PNT requirements, compares requirements to existing technology, identifies performance short-falls, highlights needed research and development, and provides long-term projections of anticipated capabilities.

b. Service and Defense agencies' PNT requirements are validated in accordance with reference a. The resulting validated programs are reflected in this plan and become the basis for the Services' and Defense agencies' PNT programming and Program Objective Memorandum (POM) submissions to the Office of the Secretary of Defense (OSD). This plan, directed by reference b, is additionally the DOD input to the Federal Radio-Navigation Plan (FRP) (reference c) and appropriate NATO plans.

2. Cancellation. CJCSI 6130.01A, 13 February 1998, "CJCS Master Positioning, Navigation, and Timing Plan (MPNTP)," is hereby canceled.

3. Applicability. This plan applies to the Military Departments, the Chairman of the Joint Chiefs of Staff (Joint Staff), the combatant commands, and the Defense agencies.

4. Policy. DOD policy requires a consistent and logical integration of PNT systems. This includes integrating the data, schedules, programs, plans, and responsibilities for PNT systems among the Services, Defense

agencies, and commands, and between the MPNTP and the FRP. This plan provides the basis and vehicle for such integration.

5. Responsibilities. See Enclosure A, paragraph 3, sections a through g.

6. Review Procedures. This instruction will be reviewed annually and revised as necessary, normally during odd-numbered years. Recommendations for changes from the unified commands should be submitted to the Deputy Director for C4 Systems, J-6, Joint Staff, Washington, D.C. 20318-6000. Service and Defense agency recommendations should be submitted through the following addressees:

a. US Army. Deputy Chief of Staff for Operations and Plans, Attn: DAMO-FDC, 400 Army Pentagon, Washington, D.C. 20310-0400.

b. US Navy. Chief of Naval Operations, Attn: N63, 2000 Navy Pentagon, Washington, D.C. 20350-2000.

c. US Air Force. Director of Operational Requirements, HQ USAF, Space and Reconnaissance Requirements Division (HQ USAF/XORR), Washington, D.C. 20330-1480.

d. US Marine Corps. Commandant of the Marine Corps, Attn: HQMC Code CSB, Washington, D.C. 20380-0001.

e. NSA. Director, National Security Agency, Attn: DDI, Ft. George G. Meade, Maryland 20755-6000.

f. DISA. Director, Defense Information Systems Agency, Attn: DNSO, D311 DISN Transport Operations Branch, 701 South Courthouse Road, Arlington, Virginia 22204-2199.

g. NIMA. Director, NIMA, Attn: ST, 4600 Sangamore Road, Bethesda, Maryland 20816-5003.

7. Summary of Changes. This instruction has undergone a major revision. The instruction is no longer a repository for detailed description of PNT systems. The instruction now provides an overview of PNT policy and summaries of existing and planned PNT systems. Additionally, references to civil PNT systems have been removed, along with duplicated information found in other DOD directives and instructions.

8. Releasability. This instruction is approved for public release; distribution is unlimited. DOD components (to include the combatant commands), other Federal agencies, and the public may obtain copies of

this instruction through the Internet from the CJCS Directives Home Page--http://www.dtic.mil/doctrine. Copies are also available through the Government Printing Office on the Joint Electronic Library CD-ROM.

9. Effective Date. This instruction is effective immediately

For the Chairman of the Joint Chiefs of Staff:

C. W. FULFORD, JR.
Lieutenant General, U.S. Marine Corps
Director, Joint Staff

Enclosures:

A	--	Positioning, Navigation, and Timing Policy
B	--	Positioning, Navigation, and Timing Requirements
C	--	Positioning, Navigation, and Timing System Architecture
D	--	Global Positioning System Operations and Security Policy
E	--	Global Positioning System User Equipment Acquisition Policy and Equipage Status
F	--	Operational Position, Navigation, and Timing Systems -- Descriptions and Characteristics
G	--	Positioning, Navigation, and Timing Research and Development
H	--	Control of Positioning, Navigation, and Timing Systems in Times of Tension or War
I	--	Geospatial Information and Services
J	--	Precise Time and Time Interval
K	--	References
Glossary		

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Director, Office of Management and Budget	1
US Delegate to the Military Committee, NATO	2
Commander, Joint Information Operations Center	1
Secretary, Joint Staff	60

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LIST OF EFFECTIVE PAGES

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PAGE	CHANGE	PAGE	CHANGE
1 thru 4	0	F-1 thru F-20	0
i thru iv	0	G-1 thru G-12	0
A-1 thru A-4	0	H-1 thru H-2	0
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D-1 thru D-2	0	K-1 thru K-2	0
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RECORD OF CHANGES

Change No.	Date of Change	Date Entered	Name of Person Entering Change

ENCLOSURE A

POSITIONING, NAVIGATION, AND TIMING POLICY

1. Scope. This plan documents the DOD's policy, requirements, acquisition planning, operational use, and sustainment of PNT systems. It presents the status of all operational DOD PNT systems and the status of DOD PNT acquisition programs. Additionally, this plan describes major military and civilian "common-use" systems and single-Service PNT systems.

a. This plan does not cover every possible topic of timing, positioning, or navigation. For example, it makes no detailed reference to visual navigation, nor to such topics as use of navigation charts or notices to mariners.

b. This plan uses the term PNT to apply to both the end use of positioning, velocity, and timing (PVT) information as well as to the various systems which generate PVT information.

2. Summary of Key PNT Policies

a. General Military Policy. In conducting military operations described in Joint Vision 2020, it is essential that PNT services be available with the highest possible confidence. These services must meet or exceed mission requirements. In order to meet these mission requirements, military operators may use a mix of independent, self-contained, and externally referenced PNT systems. DOD PNT users may use US civil PNT systems for peacetime operations where their use does not jeopardize DOD's ability to carry out its military mission. Civil PNT systems will not be used for combat, combat support, and combat service support operations. Use of foreign PNT systems is prohibited unless a specific memorandum of agreement (MOA) has been established with that respective nation. DOD ships and aircraft may use civil PNT system(s) in peacetime scenarios as long as the system(s) in use meet International Maritime Organization (IMO), International Civil Aviation Organization (ICAO), and/or FAA specifications.

b. Survivability Requirements. PNT systems must be as survivable and enduring as the forces and weapon systems they are designed to support. The services should use physical security, hardening, electronic protection mechanisms, and other measures to ensure the availability of PNT services to the United States and its allies, while denying such capabilities to enemies.

c. Continuity. Current PNT systems must be sustained until follow-on systems have been validated for operational use.

d. Need for Periodic Reviews. The DOD will conduct periodic reviews of emerging PNT technologies to determine their ability to meet operational requirements.

e. Global Positioning System. GPS is now and will continue to be the primary radio-navigation system source of PNT information for the Department of Defense. All DOD combatant users must acquire, train with, and use GPS systems capable of receiving the encrypted, military GPS signal, the Precise Positioning Service (PPS). The National Defense Authorization Act for FY 1994 (Public Law 103-160), as amended by National Defense Authorization Act for FY 1999 (Public Law 105-261), mandates that ". . . after September 30, 2005, funds may not be obligated to modify or procure any Department of Defense aircraft, ship, armored vehicle, or indirect-fire weapon system that is not equipped with a Global Positioning System receiver." DOD PNT users may use civilian GPS augmentations for peacetime operations where their use does not jeopardize DOD's ability to carry out its military mission. Examples include the US Coast Guard's Differential Global Positioning System (DGPS) and the Federal Aviation Administration's Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS), currently under development. It is essential for users to understand that these systems may not be reliable during conflict, as they do not incorporate the same level of security and survivability as military systems.

f. C4ISR Systems Timing Policy. C4ISR systems that rely on GPS for timing shall use only secure PPS receivers and incorporate the capability to operate without continuous GPS availability or integrity.

3. Responsibilities. The responsibilities of DOD organizations for PNT systems are delineated in DOD Directive 4650.5 (reference b), as modified by the Deputy Secretary of Defense letter dated 8 September 1998 (reference i). Additional responsibilities are as follows:

a. The Chairman of the Joint Chiefs of Staff is responsible for DOD PNT operational matters. These functions include:

(1) Developing joint PNT operational doctrine and tactics for use of PNT equipment.

(2) Reviewing Service budgets to ensure satisfaction of validated-PNT requirements, to avoid duplication of effort, and to prevent expenditure of funds on systems scheduled to be phased out.

(3) Promoting standardization, interoperability, and compatibility to fulfill common requirements.

(4) Coordinating PNT matters affecting NATO and individual nations.

(5) Providing direction and inputs for the development of a navigation systems architecture that describes operating concepts, system developments, replacement plans, and alternatives for satisfying validated requirements.

(6) Participating in PNT committees and working groups, as required.

(7) Preparing, reviewing, and publishing the CJCS MPNTP in coordination with the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (ASD(C3I)), the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)), and the Military Departments.

b. Within their respective commands, CINCs perform functions of the same general nature as those of the CJCS, including planning for the operational employment of PNT systems in war and contingency plans. CINCs may develop PNT requirements in support of contingency plans and CJCS-directed or CJCS-coordinated exercises that require not only their own, but also other PNT resources. CINCs are also responsible for reviewing the CJCS MPNTP, suggesting changes, establishing requirements, and implementing the plan.

c. USCINCSPACE will operate GPS as described in reference f. The PPS will be operated in accordance with reference e. The Standard Positioning Service (SPS) will be operated in accordance with reference d. The decision to alter SPS performance to introduce intentional errors will be made by the National Command Authorities (NCA) after recommendation by the CJCS following a request by a CINC. USCINCSPACE will operate and maintain the GPS Support Center, which provides problem reporting and resolution and mission planning support to the Department of Defense.

d. NIMA is responsible for geospatial information and services (GI&S) support to DOD navigation systems. That support includes charts, digital terrain elevation data, digital feature analysis data, digital hydrographic chart data, point-positioning data bases, geodetic surveys, the World Geodetic System 1984 (WGS 84), and associated tables that are compatible with and meet the accuracy objectives approved by the Chairman of the Joint Chiefs of Staff. GI&S support also includes geodetic positioning of transmitters for electronic systems and tracking stations for satellite systems, maintenance of GPS-fixed site operations, and generation and distribution of GPS precise ephemerides. NIMA acts as the primary point of contact with the civil community on matters relating to geodetic uses of DOD navigation systems and provides calibration support for certain airborne navigation systems.

e. The NSA is responsible for the development of cryptographic devices and techniques used to deny the unauthorized use of PNT systems information. The Joint Staff will approve operational concepts and plans that establish PNT security requirements and procedures.

f. The US Navy, through the US Naval Observatory (USNO), is responsible for establishing, maintaining, and coordinating the astronomical reference frame(s) for celestial navigation and orientation of space systems. The US Navy, through the USNO, is also responsible for deriving and maintaining standards for precise time and time interval (PTTI) and ensuring uniformity in PTTI operations.

g. The Interagency GPS Executive Board (IGEB) is responsible for the management of the dual use aspect of GPS and its USG-provided augmentations. The IGEB is co-chaired by the ASD(C3I) and the Assistant Secretary for Transportation Policy (from the Department of Transportation). Other USG agencies making up the IGEB membership include the Departments of State, Commerce, Agriculture, Interior, and Justice; National Aeronautics and Space Administration; and the Chairman, Joint Chiefs of Staff. The IGEB is tasked to manage GPS and its USG-provided augmentations. The IGEB's functions include reviewing the status and plans for continued development, acquisition, and operations of GPS affecting dual use, approving management policies, resolving interdepartmental issues, preparing periodic status reports to the President, and consulting with USG agencies, US industry, and foreign governments on issues involving GPS.

ENCLOSURE B

POSITIONING, NAVIGATION, AND TIMING REQUIREMENTS

1. General Requirements. It is DOD policy to develop, procure, and sustain PNT systems to meet the full spectrum of military operations. It is also DOD policy that military platforms conducting peacetime operations will conform to applicable rules to ensure interoperability and transparency within domestic and international controlled airspace, on the high seas, and on coastal and inland areas. To meet operational requirements, the ideal PNT system should have the following characteristics:

a. Worldwide coverage.

b. User-passive.

c. Capable of denying and degrading use by adversaries while not impacting friendly military operations or unduly disrupting civil users.

d. Able to support an unlimited number of users.

e. Resistant to countermeasures. Systems should be as survivable and endurable as the forces and weapon systems they support including hostile attack, electromagnetic pulse (EMP), and natural disturbances.

f. Real-time response.

g. Interoperable among DOD Services and allied/coalition partners.

h. Free from frequency allocation problems.

i. Common grid or map datum reference for all users.

j. Common time reference for all users.

k. Accuracy that is neither degraded by changes in altitude for air and land forces, in high-g or other violent maneuvers, nor by time of year or day.

l. Maintainable by personnel at the user's location.

m. Self-contained.

n. Availability not limited by altitude, terrain, structures, or depth of water.

o. Possess system integrity.

p. Reliable.

q. Provide four-dimensional information (i.e., x, y, z, and time).

r. Certifiable for applications involving civil airspace operations.

2. <u>Operational Survivability Requirements</u>. PNT systems must be as survivable and enduring as the forces and weapon systems they are designed to support. Terrestrial-based systems (tactical navigation (TACAN), microwave landing system (MLS), instrument landing system (ILS), etc.) must employ physical security measures that reduce vulnerability to sabotage or terrorist attack. Rapid reconstitution plans, including plans for replacement transmitters, use of rugged construction techniques, and conventional and nuclear hardening should be considered. Space-based systems must be hardened against EMP to at least the same level as the forces the system supports. Transmission and reception techniques to prevent jamming and other interference must be employed. Additionally, methods need to be employed to prevent hostile exploitation of PNT systems and to deny use of such systems to military adversaries or other combatants. Physical security measures must be in place to minimize the impact of attempts to destroy or incapacitate satellite ground-control segments.

3. <u>Aviation Requirements</u>. Aircraft must be equipped with instruments and navigation equipment appropriate to the routes to be flown. The FAA issues technical standard orders (TSOs) that prescribe minimum performance standards for navigation equipment used by the civil aviation community in the National Airspace System (NAS). The ICAO issues standards and recommended practices (SARPS) for international civil aviation. The development of minimum performance standards for military users is the responsibility of the Services. These military standards must conform with civil airspace required navigation performance (RNP) requirements, prevent violation of civil air traffic clearances, and ensure safe separation of military and civil air traffic. While meeting the ICAO SARPS is essential, military combat and combat support aircraft must have PNT capabilities designed to operate in a combat or stressed environment where civil PNT services are likely to be jammed or severely limited.

ENCLOSURE C

POSITIONING, NAVIGATION, AND TIMING SYSTEM ARCHITECTURE

1. General. No single PNT system currently supports all of DOD's PNT requirements as outlined in Enclosure B. Therefore, the DOD PNT architecture summarized in this enclosure contains of a mix of PNT systems. Until such time as a system can be identified or developed to meet all operational requirements, a mix of systems will continue to exist.

2. Architecture. The DOD PNT architecture consists of systems that are used in combat and combat support operations and systems that support worldwide peacetime operations. The challenge for DOD is to minimize the costs to equip platforms to operate in both environments while minimizing the necessity to maintain duplicative systems.

a. Combat and Combat Support Operations. Table C-1 lists the externally derived (e.g., does not address inertial navigation systems (INS)) PNT systems that may be used for combat and combat support operations and cross-references these systems with the PNT requirements from Enclosure B. Details of the systems in Table C-1 are contained in Enclosure F.

	GPS (PPS)	Radio-Beacons	VHF Omni-Range	DME	TACAN	ILS	PALS	C-SCAN	MRAALS	MATCALS	MMLS	DF	GCA/PAR
Worldwide Coverage	X												
Passive	X	X	X	X	X	X		X	X	X	X	X	X
Deniable	X	X	X	X	X	X	X	X	X	X	X	X	X
Unlimited # of Users	X	X	X	X	X	X		X	X	X	X	X	X
ECCM Capable	X												
Real Time	X	X	X	X	X	X	X	X	X	X	X	X	X
Interoperable	X	X	X	X	X	X	X	X	X	X	X	X	X
Protected Spectrum	X[1]	X	X	X	X	X	X	X	X	X	X	X	X
Common Grid	X												
Accurate	X					X	X	X	X	X	X		X
Maintainable	X	X	X	X	X	X	X	X	X	X	X	X	X
Self-Contained	X	X	X	X	X	X	X	X	X	X	X	X	X
Unimpeded Availability													
Integrity				X	X	X	X	X	X	X	X		X
Reliable	X	X	X	X	X	X	X		X	X	X		X
(x, y , z, and time)	X												
Certifiable	X		X	X	X	X					X		X

[1] The World Radio Council (WRC) 2000 will be addressing spectrum sharing in this band proposed by the international Mobile Satellite System (MSS) industry.

Table C-1. PNT Requirements (Enclosure B) as Compared to Military PNT Systems (Enclosure F)

b. Noncombat Operations. The FRP contains descriptions of federally provided PNT systems that are available for noncombat applications for DOD platforms. To minimize duplication of information contained within the current FRP, these systems are not listed here. DOD users are reminded of the policy as stated in Enclosure A, subparagraph 2a, on the use of civil PNT systems for combat and noncombat operations.

3. Current PNT Systems Architectures. The DOD PNT architecture consists of a mix of PNT systems, as no single PNT system meets all of DOD's operational requirements. However, GPS is now and will continue to be the primary radio-navigation system source of PNT information for the Department of Defense. Enclosure F contains details on each PNT system that are currently part of the DOD PNT architecture.

4. Future PNT Systems Architectures. Determination of what PNT systems are to be maintained to fulfill DOD requirements is a function of costs (operations and maintenance), the mission criticality being served by a specific PNT system, and the redundancy requirements necessary to conduct a DOD mission.

a. As GPS is now and will continue to be the primary radio-navigation system source of PNT information for the Department of Defense, it has become an area of significant focus. On 16 June 1999, the Joint Requirements Oversight Council (JROC) approved the GPS operational requirements document (ORD) and validated the key performance parameters (KPPs). The JROC confirmed that the KPPs will provide the operational capability necessary for GPS to satisfy the mission needs. As the requirements are validated, this ORD will be the basis for the Services' and Defense agencies' programming and POM submissions to OSD. These new validated requirements will feed the modernization of GPS to meet new and expanding military requirements. Details on the GPS modernization effort are found in Enclosure G.

b. Another area with significant focus today is the development of a system architecture to equip DOD platforms with the capabilities to fly in controlled airspace using GPS. The Air Force Director of Operations has the DOD lead in considering what must be done to use the GPS PPS in controlled airspace. The most likely solution to this problem is for DOD to use avionics that include an SPS-mode for use in civil-controlled airspace. The global air traffic management (GATM) architecture is the USAF's effort to ensure appropriate USAF aircraft comply with the FAA/ICAO communications, navigation, surveillance, and air traffic management requirements. Implementing this architecture will involve significant investment by the Department. The US Navy has a similar program to ensure compliance with FAA/ICAO requirements, and refers to it as communications, navigation, surveillance-air traffic management (CNS-ATM).

c. One program related to the GATM architecture is the joint precision approach and landing system (JPALS). The Phase 0 JPALS, analysis of alternatives (AOA), recommended the most promising backbone of the long-term JPALS architecture would include the Local Area Differential Global Positioning System (LDGPS) and the automatic carrier landing system plus (ACLS+). At the conclusion of the ongoing Phase 0 Architecture Requirements Definition effort in FY 02, the Milestone I/II review will include recommendations for the final JPALS solution and a transition roadmap. Existing systems that may be replaced or phased down by JPALS include ILS, MMLS, GCA/PAR, MRAALS, instrument carrier landing system (ICLS), ACLS (with ACLS+), and shipboard TACAN.

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ENCLOSURE D

GLOBAL POSITIONING SYSTEM OPERATIONS AND SECURITY POLICY

1. Policy. The Military Departments, the Joint Staff, the combatant commands, and the Defense agencies will comply with established policy (reference e).

2. Summary. The Department of Defense intends to operate the GPS to provide a military advantage for the United States and its allies over any adversary. At the same time, GPS SPS will be available for peaceful civil, commercial, and scientific use on a continuous, worldwide basis, free of direct user fees. On 1 May 2000, the President announced that the United States would discontinue the use of selective availability (SA) effective 2 May 2000. This decision allows civil users access to the full benefits of GPS navigation and timing. With the discontinuance of SA, the Department of Defense intends to prevent the hostile use of GPS in combat areas through its Navwar program, with a goal of conducting prevention activities without unduly interfering with the peaceful use of GPS outside combat areas. Department of Defense, allied, and friendly foreign military GPS users will use the PPS to ensure exclusive use of the full capability of GPS.

3. Procedures for Altering SA or Anti-Spoofing. A military request to change the GPS operating mode or alter the SPS accuracy level will originate with a combatant commander. It will be addressed to the Chairman of the Joint Chiefs of Staff and include the Secretary of Defense and USCINCSPACE as information addressees. A decision to degrade SPS accuracy or to change the GPS operating mode must be approved by the NCA. If time and circumstances permit, the Department of Defense will consult with the Secretary of Transportation. Civil users will be notified via the notice to airmen (NOTAM) and notice to mariners systems. DOD agencies will forward requests for operating mode changes to the Chairman of the Joint Chiefs of Staff via the Joint Staff in peacetime scenarios with a minimum of 90 days advance notice. Defense agencies should send information copies of these requests to the USD (A&L), the Assistant Secretary for Transportation (Policy), and USCINCSPACE. Non-DOD agencies will forward requests for SA/anti-spoofing (A-S) status changes to the Assistant Secretary for Transportation (Policy). In peacetime scenarios, USSPACECOM will ensure a minimum of 30 days advance notice of GPS operational mode changes is given to all users. Sixty days advance notice will be the goal.

4. DOD Differential Policy. The Department of Defense will operate insofar as possible using the PPS received directly from the GPS satellite constellation as the primary source of PNT information. Additionally, the

Department of Defense is considering methods to improve the direct reception accuracy available from PPS to satisfy high-precision positioning, timing, and navigation needs in authorized military platforms without requiring differential corrections. To the extent the Department of Defense uses differential GPS for combat operations, the differential systems must use the PPS, and the differential corrections must be encrypted for transmission and processing. DOD PNT users may use US civil DGPS systems for peacetime operations where their use does not jeopardize DOD ability to carry out its military mission. Use of foreign DGPS systems that are not provided by countries with defense arrangements with the Department of Defense are prohibited. The preceding prohibitions do not apply to ships and aircraft in peacetime navigation scenarios as long as the system(s) in use are IMO- or ICAO-recognized systems, respectively.

a. The Department of Defense plans to deny access to C/A code signals, C/A code-derived DGPS, and other precise PNT systems in local combat theaters or other areas of national security interest.

b. DOD GPS users may use civilian-provided SPS-based DGPS services when civil agencies have defined navigation accuracy, integrity, availability, and continuity of service requirements that exceed direct reception PPS capabilities, where operation is in the interest of the Department of Defense, and such use does not result in adverse effects to military missions.

ENCLOSURE E

GLOBAL POSITIONING SYSTEM USER EQUIPMENT ACQUISITION POLICY AND EQUIPAGE STATUS

1. Objective. The objectives of the DOD user equipment acquisition policy are to:

a. Support employment of GPS as the primary radio-navigation system and standard source for accurate time and time synchronization for use by all forces.

b. Preserve the military competitive advantage and force enhancement capabilities derived from direct access to the GPS-PPS.

c. Preclude duplication of user equipment development efforts and associated costs by concentrating the development of common military user equipment at the GPS Joint Program Office (JPO).

d. Enable the Department of Defense to benefit from the rapid technological advances occurring in the civil GPS market.

e. Promote the purchase of user equipment from competitive sources that have been technically and security prequalified by the GPS JPO.

f. Ensure DOD airborne users conform to the requirements for operation within the National Airspace System (NAS) and within the International Civil Aviation Organization (ICAO) airspace.

g. Facilitate the automatic acquisition/utilization of GPS-PPS timing information by weapon systems.

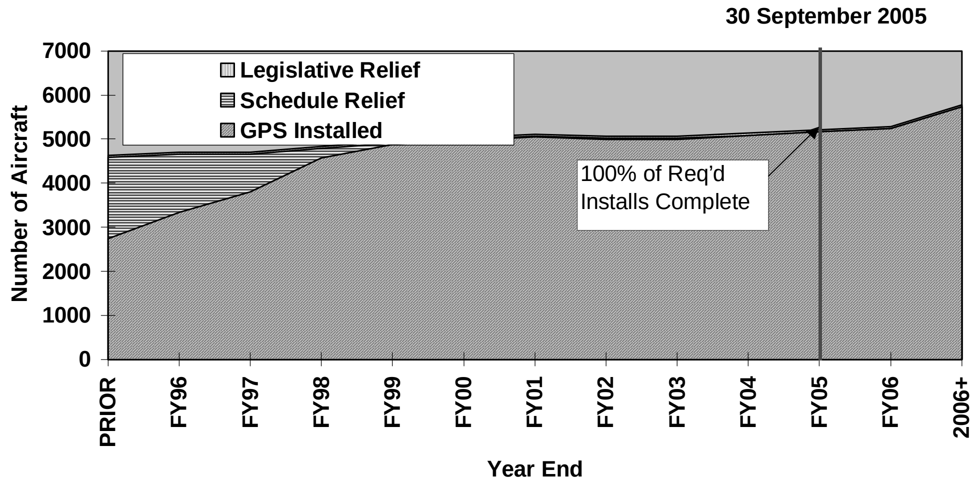
2. Acquisition Policy

a. Except for congressional exceptions for range instrumentation, advanced technology, mapping, special forces, and classified applications, all DOD common user equipment will be developed and procured through the GPS JPO. Waiver requests for special applications should be submitted to the Office of the Assistant Secretary of Defense (C3I) (OASD (C3I)) through the Service Acquisition Executives on a case-by-case basis.

b. Development and acquisition of special application user equipment shall be coordinated with the GPS JPO to ensure compatibility with the GPS signal in space and compliance with GPS security requirements and reference g.

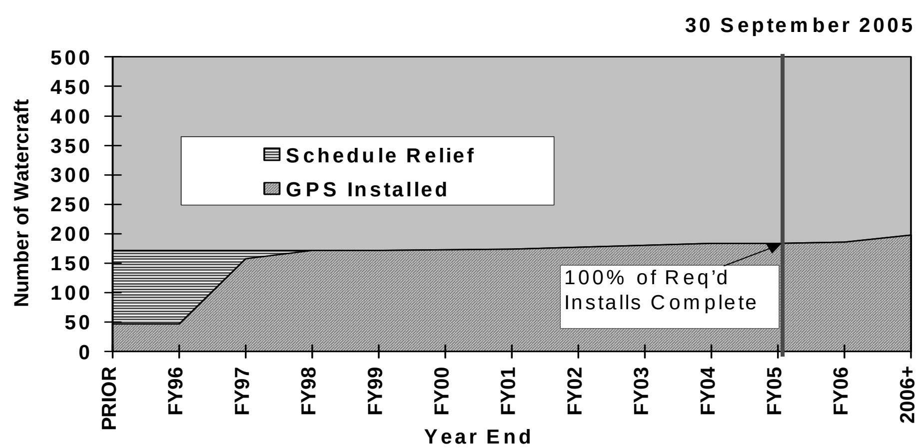
c. GPS user equipment intended for use on DOD aircraft operating in civil airspace will meet established standards for accuracy, integrity, and safety. Consistent with operational capability, acquisition of airborne user equipment will include a process to identify and mark the equipment with the class codes found in the applicable FAA TSOs, alternative military standards, or other applicable civil standards. User equipment installations will meet the performance standards for operations in civil airspace. The JPO will ensure that GPS user equipment procured or developed through the JPO for aviation applications will satisfy the certification requirements for operations in civil airspace. Actual certification of the GPS user equipment will be performed by the Services.

3. GPS Equipage Status. Section 152(b) of the National Defense Authorization Act for Fiscal Year 1994 (Public Law 103-160; 107 Stat. 1578) placed limitations on procurement of systems not GPS equipped. This mandate, termed GPS 2000, prohibited obligation of funds to modify or procure any DOD aircraft, ship, armored vehicle, or indirect-fire weapon system not equipped with a GPS receiver after 30 September 2000. The National Defense Authorization Act for Fiscal Year 1999 (Public Law 105-261) extended the 30 September 2000 date to 30 September 2005. Equipping all affected DOD platforms is occurring at varying rates. The following charts show GPS user equipment installation progress for DOD platforms as of the publication of this instruction.



Legislative Relief	Schedule Relief	No Reqt for Future Mod
TH-67 (45) (VFR-only trainer)	None	None

Table E-1. GPS User Equipment Installation Progress -- USA Aircraft



Legislative Relief	Schedule Relief	No Reqt for Future Mod
None	None	None

Table E-2. GPS User Equipment Installation Progress -- USA Watercraft

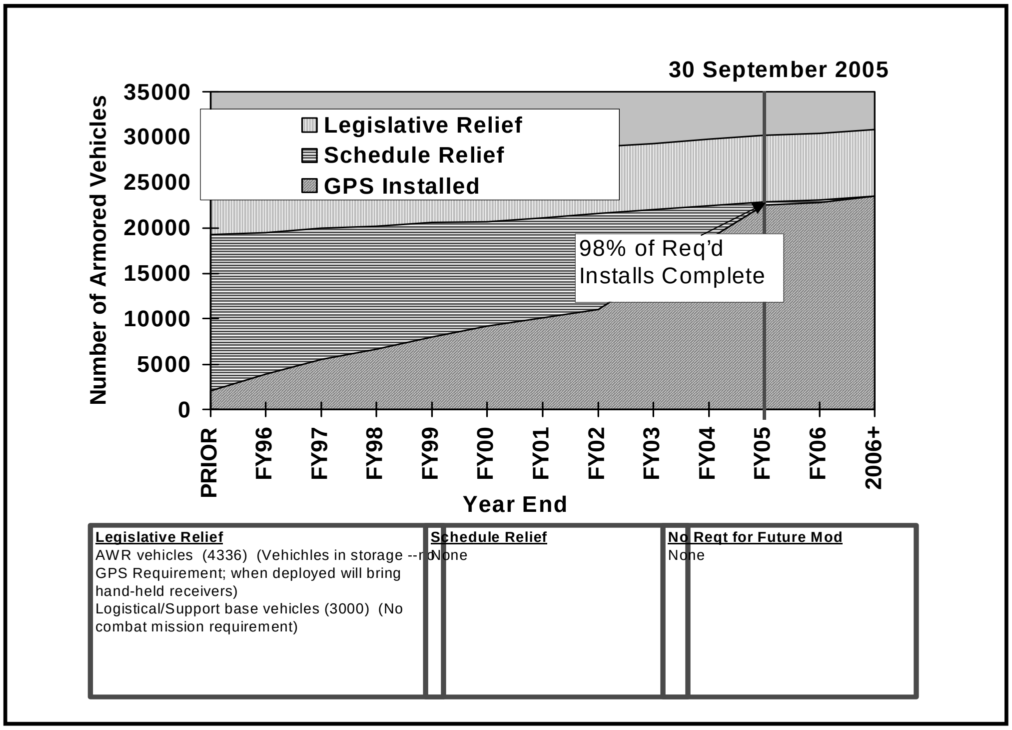


Table E-3. GPS User Equipment Installation Progress -- USA Armored Vehicles

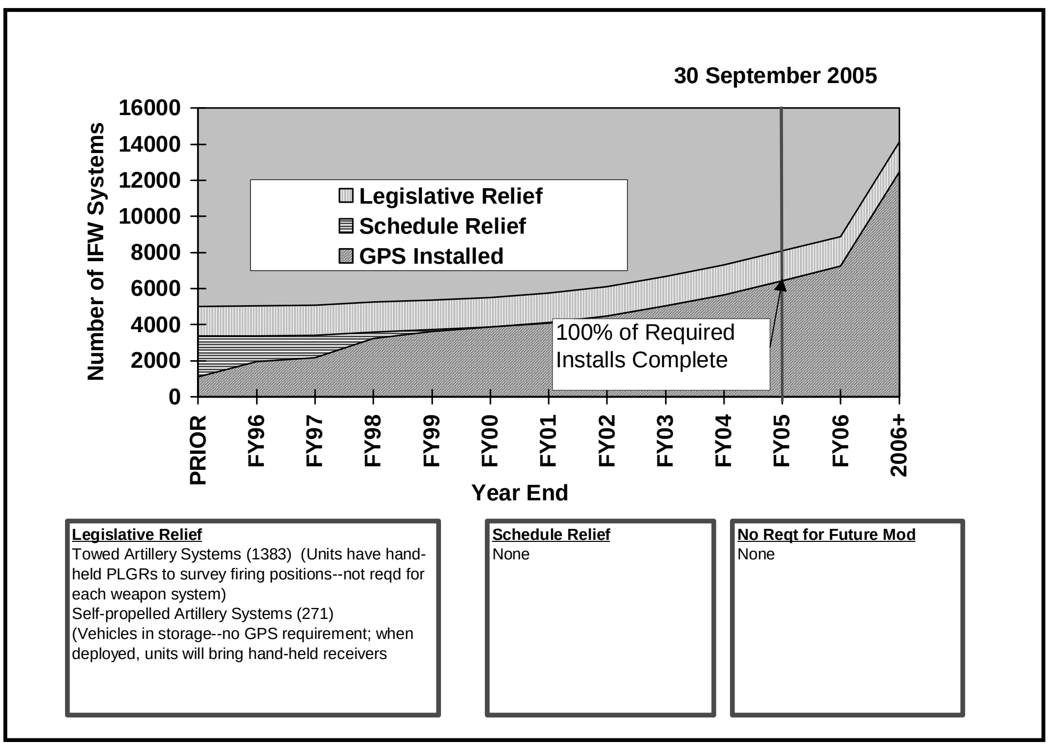
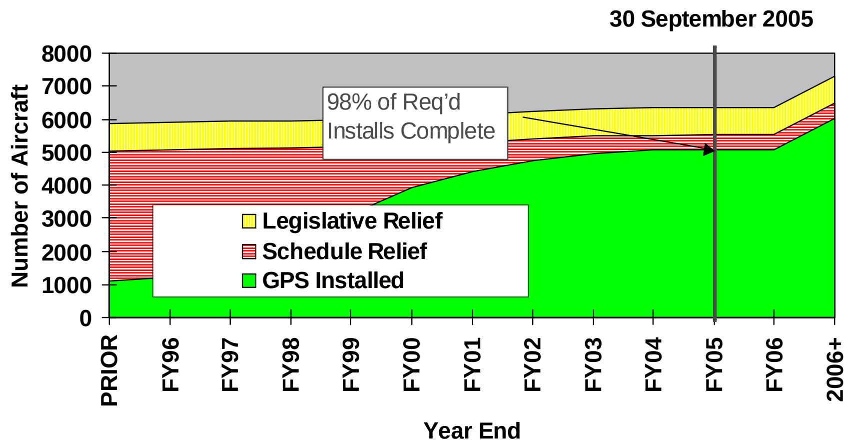


Table E-4. GPS User Equipment Installation Progress -- USA Indirect Fire Weapons



Legislative Relief

E/TE-2C	(3)	(Retirement)
F-5E/F	(34)	(Retirement)
TC-18F	(2)	(No Requirement)
TC130G	(1)	(Retirement)

Schedule Relief

T-45C	(66)

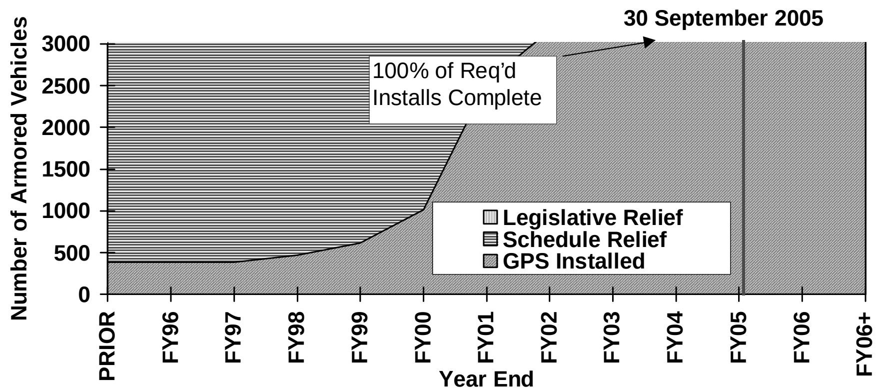
No Reqt for Future Mod

None

Table E-5. GPS User Equipment Installation Progress -- USN, USMC, and USCG Aircraft

100% of Required Installs are Complete for USN AND USCG Ships

Table E-6. GPS User Equipment Installation Progress -- USN and USCG Ships



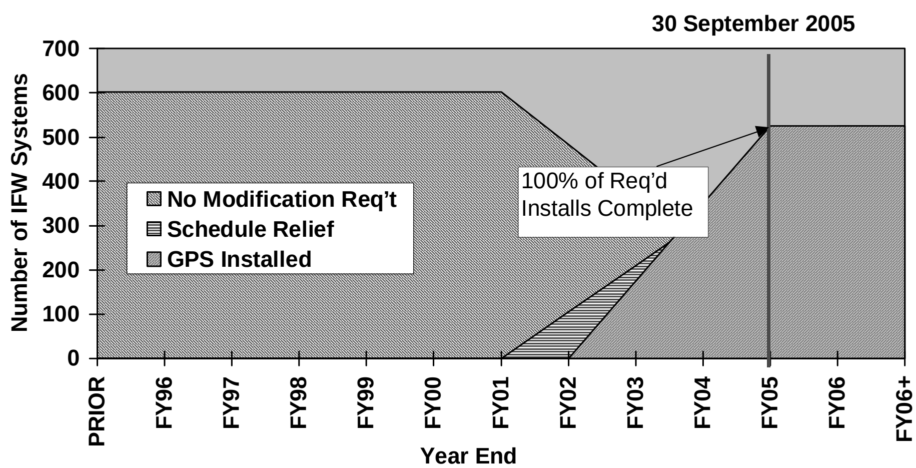
Legslative Relief (879)
M1A1 (174) (Part of MPF*)
(87) (Tank retriever)
(37) (Bridge Launcher)
LAV (63) (Part of MPF)
(139) (Non-shooter)
AAV (315) (Part of MPF)
(64) (Logistic/support)

Schedule Relief (957)
LAV (118) Completion with PLGR & DACT** Procurement (FY01)
AAV (739) Completion with PLGR & DACT Procurement (FY03)

No Reqt for Future Mod
None

* MPF - Maritime Preposition Force
** DACT - Digital Automated Communications Terminal

Table E-7. GPS User Equipment Installation Progress -- USMC Armored Vehicles

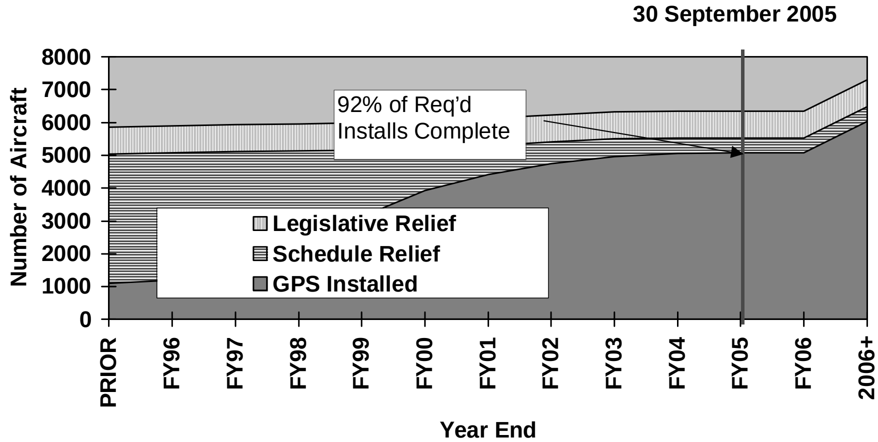


Legslative Relief
LW155 (105) Production of 526 total begins FY02. GPS product improvement begins FY03. Currently artillery firing units have PLGR assisted site survey.

Schedule Relief

No Reqt for Future Mod
M 198 (Howitzer) (603) Replaced by LW155 beginning FY02. Currently artillery firing units have PLGR assisted site survey.

Table E-8. GPS User Equipment Installation Progress -- USMC Indirect Fire Weapons



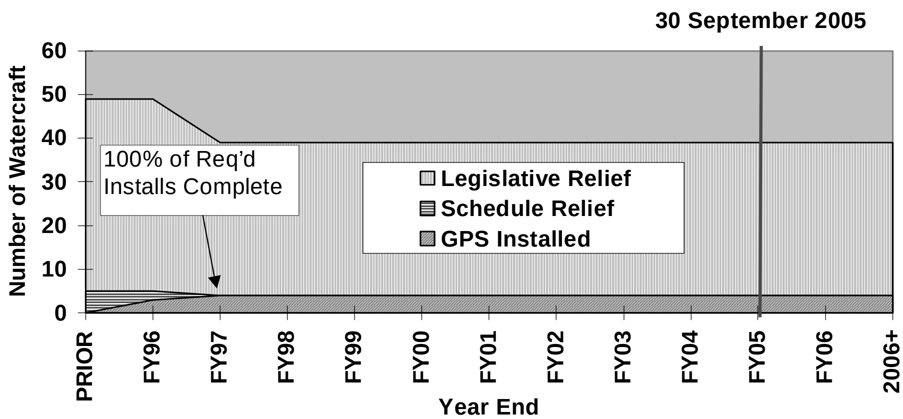
Legislative Relief

F-15A-D	(173)	(No operational reqt)
F-15A-D	(44)	(Retirement)
T-37	(473)	(Retirement)
T-3	(110)	(VFR-only trainer)
TG-3,4,9,10	(19)	(Gliders, No Reqt)
VC-137	(5)	(Retirement)
Note: U-2	(35)	(waiver required)

Schedule Relief
F-15A-D (309)

No Reqt for Future Mod
None

Table E-9. GPS User Equipment Installation Progress -- USAF Aircraft



Legslative Relief
Watercraft (34) (No requirement for GPS--Small craft, good weather, close to shore)

Schedule Relief
None

No Reqt for Future Mod
None

Table E-10. GPS User Equipment Installation Progress -- USAF Watercraft

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ENCLOSURE F

OPERATIONAL POSITION, NAVIGATION, AND TIME SYSTEMS -- DESCRIPTIONS AND CHARACTERISTICS

1. General. This enclosure describes the characteristics of operational PNT systems currently used by the Military Services and DOD agencies. Two general categories of PNT systems are described:

a. PNT systems that use radiated signals from an external PNT source for navigation or relative bearing and distances determination.

b. Self-contained PNT systems that do not require reception of externally generated signals and can provide capabilities that may not be available from radio-navigation systems in a hostile environment. Major PNT system requirements that have universal use are discussed using the parameters addressed in Enclosure B. Special or limited-use systems are described briefly, and information regarding system performance parameters have been included where practicable. Current or deployed systems are discussed in this enclosure. Developing systems are discussed in Enclosure G. GPS is now and will continue to be the primary radio-navigation system source of PNT information for the Department of Defense. As GPS is more fully utilized, a number of the PNT systems listed in this enclosure will be phased down. For PNT systems in this category, a target date to begin phasedown is provided.

2. PNT System Performance Parameters. Systems described in this plan are defined in terms of system performance parameters that determine their use and limitations. A description of these parameters are as follows:

a. Accuracy. Accuracy is the degree of conformance between the estimated or measured navigation, positioning, or timing output parameter of a platform at a given time and its true navigation, positioning, or timing output parameter. Because accuracy is a statistical measure of performance, a statement of the accuracy of a navigation system must include a statement concerning the probability level of the estimate or measurement. Specifications of PNT system accuracy generally refer to one or more of the following definitions:

(1) Geodetic Accuracy. The accuracy of a position with respect to the known, surveyed geodetic coordinates of points on the Earth.

(2) Geodetic Repeatable Accuracy/Precision. The level of repeatability that a user can determine position with respect to a position whose coordinates have been measured at a previous time with the same navigation system.

(3) Geodetic 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 or to some reference point such as a beacon or buoy. Relative accuracy may also be expressed as a function of the distance between the two users. For example, a GPS-equipped aircraft might use the geodetic solution of another GPS receiver, located near a runway, as the destination or objective during an approach to landing.

(4) Time Transfer Accuracy. The accuracy with which a user can determine the difference between a local time and coordinated universal time (UTC) as maintained by the USNO.

b. Availability. The availability of a PNT system is the percentage of time that the services of the system are usable. This is a function of both the physical characteristics of the environment and the technical capabilities of the transmitter. Availability is also an indication of the system's ability to provide usable service within the specified coverage area. Signal availability is the percentage of time that navigational signals transmitted from external sources are available for use. To consider a system available for aviation use in civil-controlled airspace, the system must meet both accuracy and integrity requirements.

c. Coverage. The coverage provided by a PNT system is that surface area or space volume in which the signals are adequate to permit the user to determine position 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.

d. Reliability. The reliability of a PNT 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 under given operating conditions. Formally, reliability is one minus the probability of system failure.

e. Integrity. Integrity is the ability of a PNT system to provide timely warnings to enable a user to determine when the system should not be used for PNT to support the mission or phase of operation.

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

g. Fix Dimensions. This characteristic defines whether the navigation system provides a one-dimensional line of position (LOP), or a two -- or three-dimensional position fix. The ability of the system to derive the fourth dimension (time) from the navigation signals is also included.

h. System Capacity. System capacity is the number of users a system can simultaneously accommodate.

i. Ambiguity. Ambiguity exists when the PNT system identifies two or more possible positions of the vehicle, with the same set of measurements, with no indication of which is the most nearly correct position. The potential for system ambiguities should be identified along with a provision for users to identify and resolve them.

j. Continuity of Service. Continuity of service is a civil aviation term that is defined as the probability that the navigation accuracy and integrity requirements will be supported throughout a flight operation or flight hour given that they are supported at the beginning of the flight operation or flight hour and that the flight operation is initiated and predicated on the operation of the service.

3. Radio-Navigation Systems

a. GPS

(1) Description. The GPS is a space-based positioning, velocity, and time distribution radio-navigation system. GPS is divided into three segments: (1) space; (2) control; and (3) user. The nominal GPS satellite constellation consists of 24 satellites. Each satellite generates a navigation message based on data periodically uploaded from the control segment and adds the message to a 1.023-MHz pseudo-random noise (PRN) coarse acquisition (C/A) code and a 10.23-MHz precise code (encrypted) (P(Y)) code sequence. The satellite modulates the resulting code sequences onto a 1575.42-MHz L-band carrier to create a spread spectrum ranging signal. Also, each satellite transmits the navigation message and the Y code at 1227.6 MHz. The satellite design requires minimal interaction with the ground and allows all but a few maintenance activities to be conducted without interruption to the ranging signal broadcast. The GPS control segment is composed of three major components: (1) Master Control Station (MCS); (2) ground antennas; and (3) monitor stations. The MCS is located at Schriever Air Force Base, Colorado, and is the central control node for the GPS satellite constellation. Operations are maintained 24 hours a day, 7 days a week throughout each year. The MCS is responsible for all aspects of constellation command and control, to include the following:

(a) Routine satellite bus and payload status monitoring.

(b) Satellite maintenance and anomaly resolution.

(c) Monitoring and management of GPS performance in support of all performance standards.

(d) Navigation data upload operations as required to sustain performance in accordance with accuracy performance standards.

(e) Prompt detection of and response to service failures.

(f) The National Defense Authorization Act for Fiscal Year 1998 mandates that the MCS component of the ground segment include an Alternate MCS (AMCS) by 2001. The control segment's four ground antennas provide a near-real-time telemetry, tracking, and commanding interface among the GPS satellites and the MCS. The five monitor stations provide near-real-time satellite ranging measurement data to the MCS and support near-continuous monitoring of constellation performance (approximately 92-percent global coverage with all monitor stations operational).

(2) Accuracy. The military navigation user equipment will provide a geodetic accuracy of 16 meters (m) or better spherical error probable (SEP) (17.8 m, 2 distance-root-mean-square (drms), horizontally and 27.7 m, 2 standard deviations (sigma), vertically). Velocity accuracy will be 0.2 m/sec (2 sigma) in each of the three dimensions. Accurate velocity is a critical input to various weapon delivery computers. Timing accuracy will be 100 nanoseconds (1 sigma) or better from universal coordinated time (US Naval Observatory) (UTC (USNO)). Precise time will be valuable to users who must time-synchronize other systems (e.g., the Joint Tactical Information Distribution System (JTIDS)). Observed geodetic accuracy has typically been better than specification (e.g., 8-10 m). Observed timing accuracy has typically been better than specification (see Enclosure J).

(3) Coverage. The probability of four or more satellites in view over any 24-hour interval, averaged over the globe, with a position dilution of precision (PDOP) of 6 or less, and a 5° mask angle with no obscuration, is 99.9 percent.

b. Radio Beacons

(1) Description. Radio beacons are nondirectional transmitting stations that operate in the LF and medium-frequency (MF) bands. A radio direction finder is used to measure the relative bearing to the transmitter with respect to the heading of an aircraft or vessel. Aeronautical nondirectional beacons (NDBs) operate in the 190- to 415-kHz and 510- to 535-kHz bands. Marine radio beacons operate in the 285- to 325-kHz band. The transmissions include a continuous carrier wave (CCW) or modulated continuous wave (MCW) signal to identify the station. Modulating a single carrier with either a 400- or 1020-Hz tone for Morse code identification generates the CCW signal. Spacing two carriers either 400- or 1020-Hz apart and keying the upper carrier to give Morse code identification generates the MCW signal. Some of the longer-range marine radio beacons operate on the same frequency

and are time sequenced to prevent mutual interference. The target date to complete phaseout of marine radio beacons not carrying DGPS correction signals is the year 2000.

(2) Accuracy. Accuracy of the bearing information is a function of geometry of the LOPs, compass heading, measurement accuracy, distance from the transmitter, stability of the signal, nature of the terrain between beacon and craft, and noise. Bearing accuracy is approximately:

$\pm 3°$ to $\pm 10°$	Aeronautical
$\pm 3°$	Marine

(3) Coverage. High-power aeronautical LF beacons provide reliable ground wave capability in excess of 560 km during favorable weather conditions. Marine beacons normally cover an area out to 50 nm or the 100-fathom curve.

c. VHF Omnidirectional Range

(1) Description. The VHF omnidirectional range (VOR) is a ground-based radio-navigation system used for en route, terminal, and nonprecision approach air navigation. In most areas of the world, VOR is used as the primary navigation aid for transiting nationally designated airways. VOR stations operate in the VHF frequency band of 108 to 118 MHz. At these frequencies, VOR is a line-of-sight system and the distances at which the signals can be received is a function of altitude and of transmitter power. Two signals are transmitted, one fixed and one rotating. The aircraft receiver compares the phase of the signals and produces a readout indicating the magnetic bearing to the station. There are approximately l4,000 military aircraft equipped with VOR receivers. The target date to begin phasedown of VOR is 2008.

(2) Accuracy. Predictable user accuracy (using root-sum-squared (rss) techniques) is +4.5°, relative accuracy is +4.3°, and repeatable accuracy is +2.3°.

(3) Coverage. VOR has line-of-sight capabilities that limit ground coverage to 56 km or less. At altitudes above 1,525 m, the range is approximately 190 km; above 6,100 m, the range will approach 375 km. En route stations radiate approximately 200 watts. Terminal VOR stations are rated at approximately 50 watts and are designed for use within terminal areas.

d. DME

(1) Description. DME stations are normally collated with VOR stations to provide the user with distance from the station. The DME interrogator in the aircraft generates a pulsed signal (interrogation) that, with the correct frequency and pulse spacings, is accepted by a ground

transponder. In turn, the transponder generates pulsed signals (replies) that are sent back and accepted by the interrogator's tracking circuitry. Distance is calculated by measuring the total round trip time of the interrogation and the reply. DME operates in the 960- to 12l3-MHz frequency band (except 1030 and 1090 MHz) with a separation of 1 MHz. The target date to begin phasedown of DME is 2008.

(2) Accuracy. Ground station errors are less than 0.1-nm. The overall system error (airborne and ground rss) is no greater than 0.5 nm or 3 percent of the distance to the station, whichever is greater. A precision DME working with MMLS provides 30-m (2-drms) accuracy on the last l3 km of an approach.

(3) Coverage. DME is a line-of-sight system that limits ground coverage to 56 km or less. At altitudes above 1,525 m, the range will approach 190 km. Those stations radiate 1,000 watts. Terminal DMEs radiate 100 watts and are only intended for use in terminal areas.

e. TACAN

(1) Description. TACAN is an airborne, ground- or ship-based radio-navigation system that combines the bearing capability of VOR and the distance-measuring function of DME. It uses 252 channels, in the 960- to 1215-MHz band, the same frequency band as DME. TACAN transmitters are primarily used by military users and are frequently collocated with VOR stations, particularly along federal airways. When TACAN is collocated with a VOR, the collective installation is called a combined VOR/TACAN station (VORTAC). The signal consists of rotating coarse azimuth (15 Hz) and fine azimuth (135 Hz) elements. Reference signals in the form of pulse trains are added to the radiated signal to provide electrical phase. The 135-Hz sine wave signal provides additional accuracy thereby reducing bearing error. Bearing is obtained by comparing the 15- and 135-Hz sine waves with the reference groups. The target date to begin phasedown of land-based TACAN is 2008. Sea-based TACAN will continue in use until a replacement system is successfully deployed.

(2) Accuracy. The ground station errors are less than +1.0° (+65 m at 3.75 km) in azimuth for the 135-Hz element and +4.5° (+294 m at 3.75 km) for the 15-Hz element. Distance errors are the same as DME.

(3) Coverage. TACAN has a line-of-sight limitation that restricts ground coverage to 56 km or less. At altitudes of 1,525 m, the range will approach 190 km; above 5,500 m, the range approaches 245 km. The station output power is 5 kW.

f. ILS

(1) Description. ILS is a precision approach and landing system consisting of a localizer, a glideslope, and one to three VHF marker

beacons. ILS provides vertical and horizontal guidance information during the approach to an airport runway. The localizer facility and antenna are typically located about 305 m beyond the stop end of the runway and transmit a VHF (108- to 112-MHz) signal. The glideslope facility is located approximately 305 m from the approach end of the runway and transmits a UHF (328.6- to 335.4-MHz) signal. Marker beacons are located along the approach extension of the runway centerline. Marker beacons emit 75-MHz signals and indicate to the pilot decision-height points or distance-to-the-runway threshold. The Department of Defense will continue use of ILS until a suitable precision approach replacement is developed followed by an appropriate transition period.

(2) Accuracy. For typical operations at a 3,050-m runway, the course alignment (localizer) at threshold is maintained within +7.6 m. Course bends during the final segment of the approach do not exceed +0.06°. Glideslope course alignment is maintained within +2.1 m at 30-m elevation and course bends during the final segment of the approach do not exceed +0.07°.

(3) Coverage

Localizer	±35° (10 nm) and ±10° (18 nm) from runway centerline.
Glideslope	Nominally 3° from the horizontal. Transmits a signal 1.4° (1,500 feet) wide at 10 miles from the runway threshold.
Marker Beacons	±40° (approximately) on minor axis (along approach path). ±85° (approximately) on major axis.

g. PALS (AN/SPN-42 or -46)

(1) Description. PALS is a carrier-based landing system that operates in the microwave frequency band (Ka/X-band) and in three modes. Mode 1 is automatic; the system senses deviation from the optimal heading and glideslope and automatically controls the aircraft to touchdown. Mode 2 is pilot controlled; the system transmits deviations to a cockpit instrument. Mode 3 is similar to GCA (see subparagraph 3m); in this mode a shipboard operator transmits instructions to the pilot. Also, there is a Mode 1A operation in which the aircraft is controlled automatically as in Mode 1 until it is one-half mile from the carrier. At that point, automatic control is decoupled and the pilot regains control of the aircraft.

(2) Accuracy. Azimuth and elevation, +0.044°.

(3) Coverage. The system can be used up to l5 km from the carrier, within +55° in azimuth, and -l5° to +30° in elevation relative to the landing area.

h. C-SCAN

(1) Description. C-SCAN is an aircraft carrier landing system, similar to ILS, that operates in the microwave frequency band (Ku-band). Originally designed as an independent monitor for the PALS, C-SCAN can also be used as a primary landing aid. C-SCAN provides azimuth and elevation guidance through use of a cross pointer display.

(2) Accuracy. Relative accuracy is +0.1° elevation, +0.2° azimuth.

(3) Coverage. Approximately 19 km from the carrier (+20° azimuth, 0° to 10° elevation).

i. MRAALS

(1) Description. The MRAALS is a two-person transportable, all-weather instrument landing system that transmits azimuth and elevation angle data and range data to suitably equipped aircraft. The airborne system translates the data and provides glideslope, localizer, and range and rate information to the pilot indicators. The AN/TPN-30 transmits azimuth and elevation data in the Ku-band frequency range (15.412 to 15.688 gigahertz (GHz)) and DME data in the L-band frequency range (962 to 1213 MHz). It can be set up in one of two configurations; collocated or split site. The collocated site, for landing zones, uses one AN/TPN-30 to provide azimuth, elevation, and range data. The split site, for airfields and airports, uses two AN/TPN-30s -- one at the end of the runway that provides azimuth data, and one parallel to the runway that provides elevation and range data. In the collocated configuration, the AN/TPN-30 can be remotely controlled (up to 1,000 feet) using field wire by the C-10195 and TPN-30 remote control or by the C-10194 and TPN-30 control indicator, which also provides status information. In the split-site configuration, the C-10194 and TPN-30 control indicator is used for remote control and for providing status of the two AN/TPN-30s, which are synchronized by field wire.

(2) Accuracy. At 1 km from the station, the azimuth accuracy is +1.74 m, elevation accuracy is +0.87 m. Range accuracy degrades as a function of distance and is +70 m at 1 km from the centerline.

(3) Coverage. +20° in azimuth, 0° to 20° in elevation, 18.5 km from the station.

j. MATCALS

(1) Description. The MATCALS was developed to satisfy the requirement for a precision traffic control and landing system for US Navy and US Marine aircraft at expeditionary airfields. MATCALS duplicates the functions of the carrier air traffic control center and provides operating space for air traffic and landing controllers plus supporting equipment. Initial MATCALS equipment deliveries consist of the AN/TPN-22 PAR, AN/TSQ-107 air surveillance radar (ASR) with identification, friend or foe (IFF), and the AN/TSQ-131 communications control subsystem. The AN/TSQ-107 will replace the AN/TPS-73 radar. MATCALS provides PALS mode 1, 2, and 3 landing capability and uses the same airborne equipment as PALS. The existing MATCALS ASR, PAR, and communications and control subsystems will be replaced in the 2004-2007 timeframe with the air surveillance and precision approach radar control system (ASPARCS).

(2) Accuracy. Azimuth, +3 m at 1 km from aircraft touchdown point. Elevation, +2 m at 1 km.

(3) Coverage. +23° from runway heading. Elevation, -1° to +7°. Distance advisories are available on all headings.

k. MMLS

(1) Description. The USAF has developed and deployed 33 MMLSs for contingency operations. The MMLS is being used by USAF C-130s equipped with modified commercial MLS avionics and USAF C-17s equipped with precision landing system receivers (PLSR). The PLSR is a USAF developed multimode receiver (MMR) with ILS, MB, MLS, and VOR capability. DGPS is a growth capability currently being developed for the PLSR.

(2) Accuracy. MLS azimuth and elevation accuracy for the split-site configuration on a 12,000-foot runway is +30 feet and +6 feet, respectively, at the Category II decision height of 100 feet. Azimuth and elevation accuracy for the collocated configuration on any length runway is +65 feet and +15 feet, respectively, at the Category I decision height of 200 feet. Accuracies include allowances for the avionics. The DME transponder accuracy is +33 feet.

(3) Coverage. Data over an area bounded by +40° from runway centerline, -0.9° to +15° elevation and up to 15-nm range from the runway threshold.

l. DF

(1) Description. Direction finders provide the capability to determine a relative bearing on any UHF radio transmission and are

used primarily in air traffic control and as a backup navigation system, particularly between moving platforms.

(2) Accuracy. Relative accuracy +3° to 5°.

(3) Coverage. Line of sight from the transmitter.

m. GCA and PAR

(1) Description. GCA has been a precision landing aid for military aircraft since World War II. Ground-based and shipboard precision approach radar provides the operator 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. Special aircraft equipment is not required. All voice instructions are passed by standard VHF and UHF radios. GCA and PAR are the NATO standard precision landing systems and are tactically deployable. GCA will remain operational until a suitable replacement is deployed.

(2) Accuracy. Relative accuracy is +1.3° azimuth, +1.1° elevation, and +60 range.

(3) Coverage. Approximately 18.5 km from the runway threshold.

n. Polarfix

(1) Description. Polarfix is a commercial, Gallium Arsenide (GaAs)-Laser (904 nm), range-azimuth, autotracking, positioning system. Polarfix is used by the US Navy for precise positioning on degaussing ranges, and by the US Army Corps of Engineers for hydrographic surveys.

(2) Accuracy. +0.5 m +0.01 percent of measured distance.

(3) Coverage. 5 km.

4. Radar Beacons

a. Aircraft

(1) Radar beacons are portable transponders used for targeting aerial bombardment. An aircraft interrogates the beacon transponder, and a transmission from the beacon is sent to the aircraft in response to the interrogation. The aircraft radar is then tuned so that only the coded beacon response is displayed on the radarscope. Using an offset bombing mode, the aircraft's radar crosshairs are placed on the beacon while the aircraft attacks a target that is offset at the prescribed range and bearing from the beacon.

(2) Radar beacons are used when poor terrain features provide inadequate radar returns for precise radar bombing; on targets that must

be attacked within specified times during darkness or bad weather; when there is a lack of time for detailed mission planning and target study; and to facilitate the assignment of targets after an aircraft is airborne. In a low-threat environment, the maximum offset range is within a 15-nm radius of the target, and the minimum aircraft altitude is 1,000 feet above ground level. In a high-threat environment, the maximum offset range is within a 5-nm radius of the target and the maximum aircraft altitude is 1,000 feet above the ground. Coverage degradation occurs from heavy foliage or other methods used to conceal the beacon's presence.

b. Ship. Ship radar beacons are short-range radio devices used to provide radar reference points in areas where it is important to identify a special location or to mark hazards to navigation.

5. Special-Purpose Systems (Self-Initiated)

a. Doppler

(1) Description. Doppler navigation is performed using a Doppler velocity sensor, a heading reference, and a navigation computer. Doppler navigation is dead reckoning in that it tracks changes in position from a known starting point. The Doppler velocity sensor determines aircraft velocity and drift angle by measuring the Doppler frequency shift of reflected energy from narrow radar beams transmitted at oblique angles from the aircraft toward the ground.

(2) Accuracy. 0.1 to 0.3 percent of distance traveled. When a typical attitude and heading reference system is used with an accuracy range of 0.5° to 1.5°, the Doppler navigation system error is almost completely dominated by heading errors and will range from 0.9 percent to 2.6 percent of distance traveled.

(3) Coverage. Global.

(4) Fix Rate. Continuous.

(5) Fix Dimension. 2D.

b. Terrain Contour Matching

(1) Description. Terrain contour matching (TERCOM) uses radar and barometric altimetry to determine a 3D position by comparing detected terrain profiles with prestored profiles of the terrain being traversed. Position fixes may be used to update INS or Doppler systems. NIMA is producing TERCOM data for use by cruise missiles, and there are development efforts to use the system in strategic bombers and remotely piloted vehicles.

(2) Coverage. Specifically digitized land areas.

(3) Fix Rate. One per digitized update area.

(4) Fix Dimension. 3D.

c. Bottom Contour Navigation

(1) Description. An echo sounder is used in bottom contour navigation to determine a submarine position by comparing detected terrain features with bottom contour charts of the sea bottom being traversed. Echo sounders use sonar to detect features of the ocean bottom. Bottom contour information can be used to update an INS or as a direct input to a weapon-launching system.

(2) Accuracy. Rms accuracy of bathymetric position-fixing is approximately +200 m where accurate charts, based on surveys with the requisite accuracy, are available.

(3) Coverage. Coverage is limited to areas where charts that depict bathymetric contours are available.

(4) Fix Dimension. 2D.

d. Digital Scene Matching Area Correlation

(1) Description. Digital scene matching area correlation (DSMAC) is a target area missile guidance system. Unlike TERCOM, which is a contour matching system, DSMAC utilizes actual photographs of the target area that are digitized and stored in a computer on board the missile. Missile guidance to the general target area is provided by another system such as TERCOM. Once in the vicinity of the target, DSMAC will match the digitized photograph with the surrounding terrain and correct missile guidance to the target. DSMAC is generally used with conventional weapons that require more accuracy than can be provided by TERCOM alone.

(2) Coverage. Target area only.

6. Self-Contained Systems

a. INS

(1) Description. Inertial navigation provides covert, accurate, and reliable user platform attitude, position, and velocity information and is capable of worldwide operation over a wide range of velocities, attitudes, and accelerations, regardless of weather or jamming attempts. An INS is a self-contained system that can operate autonomously (e.g., without aids external to the user platform). Before each use, an inertial navigation system must be initialized using known geodetic position and velocity. From a set position, the inertial system provides continuous estimates of position, velocity, and attitude. For all the precision and accuracy of inertial systems, the output is an estimated position and not a fix. Even the best inertials still must be updated periodically, as the

error grows with time. The key components of an INS are an inertial measurement unit (IMU), a navigation computer, and a control and display unit. The inertial measurement unit can consist of either a gyro-stabilized (e.g., gimbaled) or strapdown platform on which inertial instruments, accelerometers, and gyroscopes are mounted. In the strapdown installation, the mounting is on a nonstabilized structure attached to the frame of the vehicle. The navigation computer processes the IMU outputs to generate position, velocity, heading, and attitude data; drive navigation displays; and generates appropriate gyro-torquing commands. Also, the navigation computer provides sequencing functions to properly initialize the IMU before use as a navigator. The control and display unit displays INS data to the user and permits the user to control the INS.

(2) Accuracy. The present standard for a medium accuracy INS includes the following characteristics:

	Aircraft	Ship	Submarine
Position Drift	±1.85 km/hr	±1.85 km/30 hrs time rms	±1.85 km/14 days time rms
Velocity	±0.76 m/sec	±0.21 m/sec	±0.21 m/sec
Attitude	±2.50 arc min rms	±1.75 arc min rms	±2.00 arc min rms
Heading	±9.0 arc min ±0.030/hr	±2.00 arc min X secant lat	±2.00 arc min X secant lat

(3) Coverage. Unlimited.

b. Major INS Programs

(1) USAF Standard Navigator. The USAF has procured a series of standard inertial systems for wide application in US Air Force aircraft. After establishing a form, fit, and function specification, which describes the requirements in detail, candidate equipment was tested and qualified at the Central Inertial Guidance Test Facility. Production equipment was then competitively procured from a qualified source. Two procurements of the AN/ASN-141 were made several years apart, which were installed in A-10A, F-16C/D, HH-60A, FB-111, and EH-60 aircraft. A subsequent procurement was made competitively for the CN-1656/ASN (Litton) and CN-1656A/ASN (Honeywell), which were installed in US Air Force A-7, C-17, C-130, RF/F-4C/D/E, EF/F-111 series, HH-53, CV-22, and the US Army OV-1E aircraft. A variant of this system, employing many

common parts, but packaged in a different form factor, was used on the F-15. Another form of the standard inertial system will be installed in MC-130 E/H, AC-130H, and joint surveillance target attack radar system (J-STARS) aircraft. The modular azimuth positioning system (MAPS), a derivative of these standard inertial systems, is also being developed to meet US Army indirect fire requirements.

(2) Commercial INS. The USAF and USN have procured commercial inertial equipment, designed for use by commercial air carriers and built to Aeronautical Radio Incorporated (ARINC) 561 characteristics, for many of their cargo, transport, and patrol aircraft. The advantages of procuring such equipment are no development costs, competitive pricing, state-of-the-art accuracy, high reliability, low operating costs, and widely available service. These systems constitute one-quarter to one-third of the Services' inventory of inertial systems. Commercial system use is a form of standardization in that ARINC standard inertial systems are form and fit interchangeable. With good planning, software compatibility can be achieved among the various applications so that there is also functional interchangeability between the various aircraft, thereby providing a very broad logistic base.

(3) Carrier Aircraft Inertial Navigation System. The US Navy has developed a family of standard carrier aircraft inertial navigation system (CAINS) that meet the most stringent performance, alignment, and environmental requirements of carrier-based aircraft. The first member of this family, the AS/ASN-92 (CAINS I), was installed in the F-14A/B, E-2C, S-3A/B, ES-3A, A-6E, RF-4B, and TC-4C aircraft. The second-generation system, the AN/ASN-130A (CAINS 1A), was installed in the F/A-18A/B, AV-8B, and EA-6B aircraft. The third generation, the AN/ASN-139 (CAINS II), which incorporates ring laser gyro (RLG) technology, has been installed in the F/A-18C/D and the F-14D. The fourth generation incorporates both RLG and embedded GPS. This system is expected to be installed in the F/A-18A/B, some F/A-18C/Ds, the F-14A/B, the F/A-18 E/F, the EA-6B, and the AH-1W. The AV-8B, C-2, E-2C, and the S-3B plan to replace their existing systems with the AN/ASN-139 or the embedded GPS.

(4) Aircraft Carrier Navigation Systems. The current system consists of two AN/WSN-1(V)2 inertial systems, two AN/UYK-44 standard digital computers, and 2 CV-2953A(P) signal data converters tied into the MK-70 MOD 6 switchboard, which provides the interface between the aircraft carrier navigation systems (CVNS) and other shipboard equipment. The US Navy began upgrading this system with the WSN-7(V)3 ring laser gyro-navigator (RLGN) in FY 99, which will provide improved reliability and maintainability. This conversion is scheduled for completion in FY 02. These systems support aircraft inertial alignment.

(5) Electrically Suspended Gyro Navigation. Electrically suspended gyro-navigation (ESGN), AN/WSN-3, provides precise, self-contained, worldwide inertial navigation for SSN. The USN has developed and certified software for ESGN operation with the SSN navigation subsystems. This system is currently being replaced by the WSN-7A(V)1.

(6) AN/WSN-5 Inertial Navigation System. The AN/WSN-5 is currently being used on Aegis Cruisers (CGN-47 class), Destroyers (DDG-51 class), DD-963, LHA, and LHD to provide reference information for weapons launching and for navigation. This system is currently being replaced by the WSN-7(V)1, 2, or 3.

(7) AN/WSN-7 Ring Laser Gyro-Inertial Navigation System. The AN/WSN-7/7(A) employs three RLG and three accelerometers in a strapdown configuration. It provides precise, self-contained, worldwide inertial navigation and is the US Navy's multiplatform navigator replacing the AN/WSN-1, AN/WSN-3, and AN/WSN-5. The RLGN provides significant reliability and maintainability improvement over extant systems. In addition, it provides submarine comparable performance at reduced costs and across all platform types.

(8) AN/WSN-7B RLGN. The WSN-7B is a self-contained system whose IMU employs three RLG and three accelerometers in strapdown configuration. The WSN-7B requires external ship's speed input and periodic input of position data. While its principle function is to replace existing gyrocompasses (e.g., AN/WSN-2/2A, MK-19) it has the capability to serve as a 24-hour navigator allowing this system to provide any future weapon upgrades that may require inertial navigator inputs.

c. Attitude and Heading Reference System

(1) Description. Attitude and heading reference systems (AHRSs) are self-contained reference systems that use gyroscopes, sometimes combined with accelerometers, to establish reference data against which changes in aircraft's heading and attitudes are sensed with respect to a reference coordination system. AHRSs provide autonomous, covert, unjammable pitch, roll, and heading information to weapon systems and delivery platforms. Some versions also have magnetic variation data to compute true heading and lower-quality accelerometers to provide leveling and velocity information. AHRSs generally differ from INS in that they do not provide the quality of acceleration, velocity, true heading, and position information associated with an INS. AHRSs are used in helicopters, trainers, and as secondary reference systems for fighter/attack aircraft, certain ships, missiles, tanks, artillery, etc.

(2) Accuracy. Predictable accuracy typically is 200 arc seconds, commercial units, 1°.

d. Altimeters, Depth Finders, and Detector Systems. Pressure altimeters are used in all aircraft to determine height either above the Earth's surface or above mean sea level. For very low- and very high-altitude operations, radar altimeters are used. Depth finders are used by ships and submarines to compute distance from the keel to the sea bed. Depth detectors measure water pressure to determine a submarine's depth below the surface of the water.

e. Celestial Navigation. Celestial navigation, as traditionally practiced, provides an average error in position of 2 nm. Increased flexibility, more accurate calculations, and decreased time to solution (fix) can be achieved by performing calculations electronically. Accuracies corresponding to 15 to 30 meters on the Earth's surface are attained by automated celestial systems, depending on the degree of automation. Automated star trackers on spacecraft, missile guidance systems, and aircraft provide high-accuracy, real-time calibration of position and orientation with respect to the absolute inertial reference frame provided by stellar sources. Typically, a star tracker augments an inertial (or other) guidance system. The System to Estimate Latitude and Longitude Astronomically (STELLA) is a computer application that automates all of the calculations of celestial navigation, including derivation of a fix (2D). It is equally useful for determination of gyro/compass error, and supports the necessary planning activities for both functions with numeric and graphic displays. STELLA eliminates the need for printed tables, log and manual calculations, and can be installed on fixed, portable, or lap-top computers for use when needed. STELLA has built-in capability for higher accuracy if used in conjunction with stabilized or compensated sensors vice hand-held instruments.

7. Identification and Air Traffic Control Systems. Precise positioning; reliable navigation; identification of friendly and enemy forces; and survivable, secure communications are some of the essential elements of a commander's C3 systems. Consequently, there are current and developing systems designed to satisfy a commander's requirement to command and control forces effectively that have a PNT capability as a by-product of their primary function. Current systems are discussed in this section. Developing systems are discussed in Enclosure G.

a. Air Traffic Control Radar Beacon System

(1) Description. The air traffic control radar beacon system (ATCRBS) is a radar system designed to provide positive identification of aircraft. ATCRBS airborne transponders are set to respond to any of 4,096 possible identification codes. When interrogated by air traffic control radar, the transponder identifies the aircraft and transmits altitude information. The system operates on two discrete frequencies in

the TACAN band. In most military aircraft, the ATCRBS function is incorporated with the Mark-XII IFF system.

(2) Accuracy. Relative accuracy is +300-m range, +1.6° to +5.6° bearing.

(3) Coverage. Omnidirectional from the interrogator within line of sight (less than 250 nm).

b. Air Traffic Control Radar

(1) Description. Air traffic control radars are ground- or ship-based aircraft surveillance systems used to control en route traffic and to provide sequencing and separation in terminal areas.

(2) Relative Accuracy. +150-m range, +1.2° bearing.

(3) Coverage. Dependent on altitude.

8. Fire Control Position/Azimuth Equipment

a. Stabilization Reference Package/Position Determining System. Stabilization reference package/position determining system (SRP/PDS) is used on the multiple-launch rocket system. The SRP provides direction, elevation, and cant (slant) angle to the fire control system. The PDS provides position location data utilizing input from the SRP and two odometers connected to the vehicle tracks. The system must be initialized and updated at survey control points.

b. Position and Azimuth Determining System

(1) Description. Position and azimuth determining system (PADS) is a self-contained INS used to provide field artillery survey data universal transverse mercator (UTM) coordinates, heights, and direction) critical to weapon systems and target acquisition platforms.

(2) Accuracy. Four-m (CEP) horizontal, 2-m (PE) vertical, and 0.4-mil (PE) directional using 5-minute zero velocity updates; or -- m (CEP) horizontal, 3-m (PE) vertical, and 0.4-mil (PE) directional using 10-minute zero velocity updates.

(3) Coverage. Seven-hour or 55-km mission duration.

c. Survey Instrument, Azimuth Gyro, Lightweight

(1) Description. Survey instrument, azimuth gyro, lightweight (SIAGL) is a man-portable, north-seeking gyroscope that is capable of determining true north. USA engineers use SIAGL and artillery survey sections to determine directions needed to conduct survey operations in a combat zone.

(2) Accuracy. Predictable accuracy of bearing information is +0.150 mil divided by the cosine of the latitude.

(3) Coverage. Worldwide from 0° to 75° latitude.

d. North-Seeking Gyro

(1) Description. The north-seeking gyro (NSG) is a vehicular-mounted gyroscope capable of determining true north. It is used on artillery fire support team vehicles (FIST-V) to provide direction and elevation altitudes for the laser designator.

(2) Relative Accuracy. Azimuth error 8.5 mils (1 sigma) after 1 hour, vertical angle error 3.5 mils (1 sigma) after 1 hour.

(3) Coverage. Worldwide from 0° to 75° latitude.

9. Joint Tactical Information Distribution System/Multifunctional Information Distribution System

a. Description. Joint tactical information distribution system/multifunctional information distribution system (JTIDS/MIDS) are command and control systems that will provide real-time, secure, low probability of exploitation and intercept, jam-resistant, and line-of-sight digital data and voice communications. Over-the-horizon (OTH) communications are possible when JTIDS/MIDS-equipped platforms act as relays for others. JTIDS/MIDS have an inherent relative navigation capability that provides relative position information and navigation in a tactical grid network. Some variants of JTIDS/MIDS terminals incorporate a TACAN capability.

b. Accuracy. The relative accuracy of a fix obtained from JTIDS is 75 m, provided there is a minimum of four platforms in suitable geometric position.

c. Coverage. Tactical theater.

10. Two-Way Satellite Time Transfer

a. Description. Time transfer via satellite (two-way satellite time transfer (TWSTT)) provides comparison and synchronization to remote precise time stations and international timing centers with the DOD time standard provided by the UTC (USNO). Time transfers take place via commercial (Ku-band, 11-14 GHz), geostationary, and DOD DSCS (X-band, 7-10 GHz) satellites between fixed and portable time transfer stations. Time transfer takes place at least daily and in some cases hourly. The time comparisons are made with remote sites worldwide.

b. Accuracy. Time transfer accuracy is 1 nanosecond.

c. Coverage. Time comparisons are made with remote sites worldwide.

11. Network Time Protocol

a. Description. Computer network time synchronization is a system of distributed network time servers that provide an accurate and reliable time synchronization service for computers on the Internet and SIPRNET. The protocol provided by this system is Internet RFC-1305 Network Time Protocol, version 3 (NTP). This protocol provides mechanisms to synchronize time and to coordinate time distribution by computer on the worldwide Internet. Network time transfer is achieved by robust estimation between remote systems of clock offset, network delays, and network dispersion.

b. Accuracy. Network time synchronization over the non-deterministic Internet is maintained at the millisecond level.

c. Coverage. Worldwide

12. USNO Telephone Time Voice Announcer

a. Description. The Telephone Time Voice Announcer produces an audible tick every second from the USNO Master Clock and announces the time every 10 seconds. The time is announced in both local time and UTC. The USNO operates two time announcers: one in Washington, D.C., and one at the USNO Alternate Master Clock (USNO AMC) in Colorado Springs, CO.

b. Accuracy. Time dissemination accuracy is 1 second.

c. Coverage. Worldwide telephone system.

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ENCLOSURE G

POSITIONING, NAVIGATION, AND TIMING RESEARCH AND DEVELOPMENT

1. Scope. This enclosure details key DOD research and development (R&D) efforts focused on satisfying the PNT requirements outlined in Enclosure B.

2. Objectives. The objectives of DOD PNT R&D programs are as follows:

a. Support the achievement of stated CJCS PNT goals and objectives.

b. Respond to new requirements.

c. Combine improvement of systems with reduction of life-cycle support costs.

d. Operate fewer PNT systems while satisfying more user requirements.

e. Apply emerging technologies to more effectively and efficiently use existing technologies.

f. Maintain US military superiority.

3. Service R&D Activity Related to PNT Systems

a. US Air Force

(1) GPS Control Segment Architecture Evolution Plan Upgrade

(a) Description. The GPS MCS currently runs on IBM ES/9000s to perform the Navigation and Satellite Operations missions of GPS. Since the ES/9000s are outdated and are becoming unsupportable, the Architecture Evolution Plan (AEP) endeavors to upgrade the MCS to a distributed architecture using Sun workstations and Fiber Distributed Data Interface (FDDI) local area network (LAN) for communications. Capabilities will also be added to support the new Block IIR satellites currently being deployed. Additionally, the monitor stations (MS) and ground antennas (GA), currently operating using IBM Series 1 mainframes, are being upgraded with new equipment and software to support AEP and the use of Telecommunications Control Protocol/Internet Protocol (TCP/IP) between the MSs, GAs, and the MCS. Interfaces are also being added for AFSCN remote tracking stations (ARTS) and NIMA monitoring stations.

(b) Mission to be Enhanced Through This Technology. This upgrade will dramatically improve the supportability of the MCS, GAs, and MSs through the use of a distributed architecture and C++ instead of JOVIAL (as used in the Legacy system) thus reducing cost to maintain the software and hardware being used. This effort also provides the operators and maintainers with a much more intuitive graphical user interface, based on the Motif standard, which will make the operator's tasks easier to perform and ultimately reduce the time required to train them. The addition of ARTS and NIMA monitor stations will increase position prediction accuracy and MS coverage of the GPS signal in space (SIS) by providing additional data to be used by the MCS in estimating and correcting satellite position. Support of the Block IIR mission will also improve accuracy and longevity of GPS as the Block IIR satellite is intended to replace the aging Block II/IIA satellites currently on orbit.

(2) Combat Survivor Evader Locator

(a) Description. The Combat Survivor Evader Locator (CSEL) is the next-generation, survival radio/personnel locator system designed to ensure isolated personnel are quickly and efficiently located, tracked, rescued, and returned to friendly hands. This system includes the hand-held radio (HHR) and support segment, unattended UHF base stations (UBS) for over-the-horizon communications and tracking, and software for the Joint Search and Rescue Centers. The HHR incorporates UHF/VHF voice, a Selective Availability Anti-Spoofing Module (SAASM) based military GPS receiver, secure UHF satellite communication (SATCOM) two-way data communication, nonsecure search and rescue satellite-aided tracking (SARSAT) beacon and data, and secure low probability of intercept/detection (LPI/LPD) one-way data communications capabilities. The support equipment consists of the unit-level radio set adapter (RSA), CSEL planning computer (CPC) and the associated software that loads specific mission data, crypto keys, and displays diagnostics on the radio unit. The over-the-horizon (OTH) segment includes the unattended UBS, which provides connectivity through the various data communications systems to the HHRs. The four worldwide base stations act as distribution points for relaying message between the HHRs and the numerous rescue centers. The ground segment consists of a segmented software application that is hosted on any Defense Information Infrastructure Common Operating Environment (DII COE) C2 workstation. This allows the command elements and search and rescue forces to locate and maintain communication with CSEL-equipped survivors.

(b) Mission to be Enhanced Through This Technology. CSEL replaces current survivor radios, AN/PRC-112 and AN-PRC-90, both of which have exceeded their useful service lives and are built on 60's and 70's technology. Neither radio is currently in production. CSEL provides a quantum leap forward from these current survival radios. This is accomplished through its two-way, multiple-secure communication modes, and the ability of the isolated person to provide precise location, effectively taking the search out of search and rescue. CSEL, therefore, contributes to the warfighters' ability to ensure dominant maneuver of forces in the ability to extract downed combat crews/ground teams. This ability of the combat commanders and their maneuver forces to assure rapid location and recovery of isolated personnel directly contributes to comprehensive force protection.

(3) GPS Modernization

(a) Description. GPS modernization is planned to include the addition of a new military signal (M-Code) transmitted at a higher power of 20 dB, introduction of additional cryptographic protection, changes to the data embedded in the signal, and upgrades to the satellite and ground-control segment to add new civil signals to improve civil accuracies and availability. The addition of new signals will not impact current receivers' use of existing signals.

(b) Mission to be Enhanced Through This Technology. Upgrades of GPS capabilities to minimize impact of adversarial jamming, development, and employment of new or modified systems to deny GPS use by regional adversaries, and provide greater capability to civil users.

(4) Atomic Frequency Standard R&D

(a) Description. The atomic frequency standard is essential in order to provide accurate position, velocity, and time data. Research is being performed to evolve, develop, and test current and new designs.

(b) Mission to be Enhanced Through This Technology. Provides more producible, accurate, and reliable clocks for improved user accuracy and service. This research into future technology will bolster the clock industrial base ensuring clocks for future GPS satellites.

(5) SAASM Space Functionality

(a) Description. SAASM is the next-generation security architecture for GPS PPS user equipment.

(b) Mission to be Enhanced Through This Technology. Improves ability to deny adversarial use of GPS. SAASM incorporates system level functionality. Some of its functions require modifications to the GPS space and control segments. Capability enhancement to the space system provides support and capabilities to the SAASM-based user equipment. These capabilities include over-the-air rekey (OTAR), signal authentication, and contingency recovery functionality.

(6) SAASM User Functionality

(a) Description. SAASM is the next-generation security architecture for GPS PPS user equipment. The fielding and procurement requirements for SAASM-based equipment are delineated in reference g.

(b) Mission to be Enhanced Through This Technology. SAASM minimizes the threat of key, receiver, and algorithm compromise through the incorporation of tamper resistance technology and encrypted electronic keying. SAASM improves PPS operations, security, and technology to support user maintainability at local location, worldwide coverage, and system integrity. Provides the user with first level of GPS protection, extended PPS receiver functionality, increased PPS receiver protection, advanced PPS security device technology, and second-generation GPS cryptography.

(7) Defense Advanced GPS Receiver

(a) Description. The defense advanced GPS receiver (DAGR) program will provide authorized DOD, federal civilian, and foreign military sales (FMS) users of GPS user equipment (UE) a palm-held, SAASM-based, dual frequency, PPS receiver as a replacement to the PLGR.

(b) Mission to be Enhanced Through This Technology. The DAGR will provide greater navigation and timing capabilities to authorized users. The DAGR will have all of the capabilities provided by the current PLGR. Improvements over existing systems will include an easier to understand user interface, better protection against threat systems, smaller and lighter equipment, and better overall performance.

(8) MIDS

(a) Description. MIDS is a C2 system that will provide real-time, secure, low probability of exploitation and intercept, jam-resistant, and line-of-sight digital data and voice communications. OTH communications are possible when JTIDS-equipped platforms act as relays or through satellite communication systems. MIDS has an inherent relative navigation capability that provides a relative position information and navigation in a tactical grid network. A MIDS terminal can be programmed to emulate, on a time-shared basis, the performance of a TACAN transponder.

(b) Mission to be Enhanced Through This Technology. MIDS will enhance the US Air Force's situational awareness and C2 capabilities by digitally linking tactical commander, C2 assets, and shooters. The navigational accuracy of a fix obtained from MIDS is 75 m, provided there is a minimum of four platforms in suitable geometric position.

(9) Mobile Approach Control System

(a) Description. Mobile radar approach control systems (RAPCONs) provide aircraft advisory, sequencing, separation, safety of flight services, and precision approach capabilities to aircraft at contingency locations worldwide, even when bad weather or nighttime conditions would prevent operations under visual flight rules. The Mobile Approach Control System will include an ASR, PAR, and operations center and replace the existing TPN-19 and MPN-14 RAPCONs.

(b) Mission to be Enhanced Through This Technology. Continues USAF's ability to provide long-term deployable air traffic control (ATC) radar capability. Provides automated interoperability with the National Airspace System. Reduces airlift requirements. Provides cost-effective logistics and training by procuring a single system to do the job currently performed by two redundant and noninteroperable systems. Provides upgrade path for technical improvements that do not exist in current equipment.

(10) Sensors

(a) Description. The Air Force Research Laboratory (AFRL) Sensors Directorate is doing exploratory development (6.2) work on precision PNT sensors and advanced technology development (6.3) work in reference and receiver technologies.

(b) Mission to be Enhanced Through This Technology. The aim of the 6.2 work is developing sensors capable of operating in jamming environments and to enable multiple-platform sensor-to-shooter operations. The 6.3 effort will develop technologies and exploitation techniques designed to maximize GPS jam resistance, maximize GPS positional accuracy, and improve offensive and defensive combat capabilities.

b. US Navy

(1) Operational PTTI Standards

(a) Description. Development of new clock technology for time and frequency standards application is being conducted for the Department of Defense by USNO and the Naval Research Laboratory (NRL). Research is being conducted on cesium fountain clock technology, linear trapped ion standards, cryogenically cooled sapphire microwave oscillators, and maser standards, such as hydrogen or rubidium masers. USNO and NRL are conducting research operations in conjunction with other government and civilian agencies to develop these standards into advanced, lightweight, low-power, rugged, and space-certified systems.

(b) Mission to be Enhanced Through This Technology. Improved operational standards are required for greater accuracy and timescale stability for the USNO Master Clock. Miniature atomic standards will support direct P(Y) code GPS operations in support of precise munitions. Space-based atomic clocks will increase the accuracy of time transfer that will increase the navigational accuracy of GPS and enhance signals exploitation operations.

(2) Time Dissemination

(a) Description. In order to better disseminate time reference, USNO is developing a Distributed Master Clock System as well as investigating new techniques for time transfer technology such as GPS carrier phase. Through GPS carrier phase, USNO has been able to achieve sub-nanosecond precision frequency comparisons among the participating network of stations. Results indicate that to achieve the full capability of this technique, technology to calibrate the receiving systems at picosecond levels must be developed. NRL is investigating calibration of geodetic receiving systems through the use of GPS system simulators. Techniques to provide precise time in the absence of GPS are being investigated by USNO and NRL. The most precise time transfer technique in use today by USNO is TWSTT. Extension of this technique to mobile platforms could provide an alternative less vulnerable means of providing precise time to operating forces. By using existing communication systems combined with a smaller ruggedized modem, it could disseminate highly precise and accurate time to multiple points. Investigation of this technique could encompass the new Global Broadcast Systems and other new communication capabilities being developed, including processing and information systems.

(b) Mission to be Enhanced Through This Technology. Ensured synchronization and syntonization of tactical timing centers in the absence of GPS will be achieved. Precise time users, such as high bandwidth and high data-rate communications and signal exploitation will see an increase in their capabilities.

(3) Distributed Time Standards

(a) Description. The architecture of employing distributed time and frequency standards within user systems and communication/ sensor infrastructure are being investigated. The equipment and techniques for maintaining synchronization without continuous contact with GPS and distributing local area precise time and frequency to enable a common time reference are being investigated. Distribution technologies such as SONET techniques are being explored for high-precision, local area distribution networks. User systems that maintain and interface time within the system and potentially to other systems, such as HAVEQUICK and JTIDS/MIDS, are being investigated. Other relative tactical communications systems, such as HAVEQUICK, are designed to use relative timing information for synchronization of tactical communication protocols and data transfer. These relative systems can potentially be used to distribute over their local area of coverage, timing information derived from GPS or other sources as an alternative time and frequency source. The capability of these systems to supplement system synchronization is being investigated. The technical limitations of these alternative systems are the external timing interfaces used and the ability to output sufficiently high-quality information for absolute time transfer application. Internal system biases, offsets, and delays not affecting relative operation can be major impediments to synchronization with an absolute time reference. SPAWAR Systems Center, San Diego, USNO, and NRL are investigating these applications and systems with NAVSEA.

(b) Mission to be Enhanced Through This Technology. Ensured synchronization and syntonization of tactical navigation, communications, weapons tracking and fire control systems in the absence of GPS can be achieved. High bandwidth and data rate secure communications and signal exploitation can be assured.

(4) Advanced Celestial Navigator

(a) Description. Using fully developed space-tested astro-trackers, the advanced celestial navigator (ACN) will provide day and night celestial navigation in partially obscured skies. The highly sensitive charged coupled devices, operating in the near infrared, will be able to define angles to celestial bodies to within 1 arcsecond, a sixty-fold improvement over the current hand-held visual system. Celestial fixes to within 30 meters will be common. For aircraft, altitudes to 100 feet are realizable.

(b) Mission to be Enhanced Through This Technology. When closely coupled to the INS, the ACN will provide stabilization for both position and platform alignment. For high-flying aircraft, the ACN/INS combination provides a nearly all-weather, unjammable, and precise navigation system should GPS be denied.

(5) Full-Sky Astrometric Explorer

(a) Description. Full-sky astrometric explorer (FAME) will determine stellar positions to 50 uas in the visual magnitude range 6 to 9.

(b) Mission to be Enhanced Through This Technology. FAME will enhance satellite orientation. Satellite navigation in GEO and HEO will also improve.

(6) ASPARCS

(a) Description. ASPARCS will replace the current MATCALS ASR, PAR, and communications and control subsystems, which is reaching its service-life limits. ASPARCS will consist of four subsystems: ASR, PAR, operations, and communications.

(b) Mission to be Enhanced Through This Technology. ASPARCS will be the Marine Air Traffic Control Detachment's primary means of detecting, identifying, tracking, and reporting on all air-breathing targets. An air-breathing target is defined as a manned aircraft, unmanned aerial vehicle, or cruise missile. ASPARCS will be employed by the Marine Air Traffic Control Detachment to support the tactical air traffic control mission of the Marine Air Ground Task Force. The secondary mission of the ASPARCS will be to provide for surveillance support for air defense agencies within the Marine Air Command and Control System. Additional missions will be those to support worldwide emergencies, disaster relief operations, and to serve as an interim replacement for shore-based Naval ATC systems during equipment upgrades and/or other service life extension program efforts. This system is used to support continuous instrument flight rule services.

(7) Enhanced Link-16/GPS/INS Navigation

(a) Description. The objective is to develop and demonstrate methods to enhance navigational accuracy and robustness in tactical operating environments using Link-16, GPS, and other navigation sensors in a synergistic fashion. A centralized approach will be developed to provide a fully integrated navigation solution and enhanced navigation data transfer.

(b) Mission to be Enhanced Through This Technology. High-value tactical platforms requiring the use of accurate position, velocity, and time under adverse conditions. These missions include interdiction, surveillance, littoral operations, precision strike, minesweeping, and missile defense.

(8) US Navy Day 1 A/J Aircraft Antenna System

(a) Description. The objective is to develop and test emerging phased-array antenna technologies to meet the US Navy Department's need for a small, anti-jam (A/J) GPS antenna system to replace fixed-radiation pattern antennas (FRPAs) on tactical aircraft. The major payoffs are improved anti-jam performance with substantial cost savings over conventional controlled reception pattern antennas (CRPAs).

(b) Mission to be Enhanced Through This Technology. Tactical aircraft requiring the use of accurate position, velocity and time under adverse conditions. These missions include interdiction, surveillance, littoral operations, precision strike, and minesweeping.

(9) Nonlinear Active Antenna Technology

(a) Description. The objective is to develop compact active phased-array antennas based on recent advances in nonlinear dynamics and leveraging work in active antenna design and the theory of nonlinear oscillators.

(b) Mission to be Enhanced Through This Technology. Multiple-mission areas including C4ISR, information warfare, self-defense, and force protection that require anti-jam GPS antennas.

(10) Miniature CRPA

(a) Description. The objective is to develop antenna technologies that can provide the maximum pattern agility possible from an aperture that is a fraction of a wavelength on a side. The primary expected product is a preliminary design of a direct replacement for existing FRPA aircraft antennas with enhanced GPS anti-jam capabilities at low-elevation angles.

(b) Mission to be Enhanced Through This Technology. Tactical aircraft requiring the use of accurate position, velocity and time under adverse conditions. These missions include interdiction, surveillance, littoral operations, and precision strike.

(11) JDAM GPS Miniarray

(a) Description. The objective is to develop and demonstrate a compact, high-dielectric, GPS-receiving array that is capable of nulling jammers using any of several beam-forming electronic packages. The uniqueness of this effort is in the use of patch antenna elements that reside on a high-dielectric (e = 36) substrate and are covered by a medium-dielectric (e = 9) hemispherical superstrate. This approach enables a decrease in size of over 50 percent, resulting in reduced cost for retrofit/installation.

(b) Mission to be Enhanced Through This Technology. Precision-guided munitions that require GPS under adverse conditions.

(12) F/A-18 GPS Shadowing Investigation

(a) Description. The objective is to quantify “body masking” by the F/A-18 with a GPS antenna on its upper fuselage of GPS jammers on the ground. This will be done by controlled measurements of an F/A-18 on a pedestal (“pole test”).

(b) Mission to be Enhanced Through This Technology. Tactical aircraft requiring the use of accurate position, velocity, and time under adverse conditions.

(13) Short-Time GPS Receivers DSP for Next-Generation GPS Receivers)

(a) Description. The objective is to develop the design concepts for a new-generation GPS receiver employing modern digital signal processing (DSP) technologies that promise reduced signal collection time and enhanced anti-jam and anti-spoofing performance.

(b) Mission to be Enhanced Through This Technology. Tactical aircraft, stealthy combatants, and ship operations requiring the use of accurate position, velocity, and time. These missions include manned and unmanned submersible operations, interdiction, surveillance, operations in mountainous or urban terrain, littoral operations, precision strike, and minesweeping.

(14) Submarine High-Accuracy Fiber-Optic Gyro

(a) Description. The objective is to develop and demonstrate a high-accuracy fiber-optic gyro (HIFOOG) having the performance required to replace the electrostatic-supported gyro (ESG) now used in inertial navigators aboard strategic fleet ballistic missile submarines (SSBN). Anticipated payoffs are a ten-fold reduction in the cost of ownership and a three-fold improvement in reliability.

(b) Mission to be Enhanced Through This Technology. Long-endurance, stealthy missions requiring high-accuracy covert navigation including strategic and tactical submarine operations.

(15) Atom-Interferometric Gravity Gradiometer

(a) Description. The goal is to develop and demonstrate a high-accuracy gravity gradiometer based on atom-interferometry.

(b) Mission to be Enhanced Through This Technology. Long-endurance, stealthy missions requiring high-accuracy covert navigation including strategic and tactical submarine operations.

(16) Electronic Chart Display and Information System -- US Navy (ECDIS-N)

(a) Description. The goal is to transition primary support of navigation and piloting on US Navy vessels from paper charts to an electronic charting environment in order to provide all maritime vessels with a basic navigation system that takes advantage of the interoperability aspects of command and control systems on naval vessels. The objective is to establish the interoperability, integration, and common navigation capability for naval ships to support joint and coalition missions, and to achieve the JV 2010 goal of information superiority across a full range of military operations by providing maritime vessels with the most up-to-date information in navigation products tailored to meet their warfighting requirements. This system will provide a common navigation system for exchanging geospatial information that is sometimes classified, between authorized maritime vessels and other joint and combined units afloat and ashore in the joint task force.

(b) Mission to be Enhanced Through this Technology. All facets of naval surface and subsurface warfare and special operations.

c. Joint Program Activities

(1) Joint Precision Approach and Landing System

(a) Description. The objective of joint precision approach and landing system (JPALS) is to provide the next-generation precision approach and landing system. JPALS contributes to the joint operational capability for US forces to perform assigned conventional and special-operation missions from fixed-base, tactical, shipboard, and special-mission environments under a wide range of meteorological conditions. No existing system satisfies the mission need for worldwide deployment and interoperability among the Services, and Civil Reserve Air Fleet (CRAF), JPALS will satisfy this need. Interoperability (transparent coexistence) with the national and international civil precision approach systems is also driving the need for JPALS with impending changes in the civil aviation community.

(b) Mission to be Enhanced Through This Technology. The precision approach and landing capability (PALC) MNS identifies the need for a rapidly deployable, adverse weather, adverse terrain, day-night, survivable, and interoperable system. The MNS stipulates that our forces must possess the required mobility to fight in conflicts of varying intensity, location, and circumstance without mission degradation because of visibility constraints. The Department of Defense (DOD) must be capable of sustained operations and be able to land on any suitable surface worldwide (on land and at sea), in both peacetime and hostile environments, during inclement weather conditions. The need for interoperability with national and international civil and military precision approach systems is critical. Lack of interoperability will degrade the ability of US forces to perform airlift, combat support, or other missions where host-nation interoperability is required. Existing systems do not address the total mission need and have a variety of deficiencies and shortcomings. For example, many current systems have limited deployment capability, are difficult to transport, require extended periods of time to set up, have poor reliability, are nearing the end of their service life, are becoming obsolete, and are vulnerable in hostile situations. In addition, some existing systems are manpower intensive and require extensive and continuous training of operators and support personnel. Finally, the variety of systems in use hampers joint operations and makes it difficult to realize logistics and support savings resulting in higher life-cycle costs. Existing systems that may be replaced or phased down by JPALS include ILS, MMLS, GCA/PAR, MRAALS, ICLS, ACLS (with ACLS+), and shipboard TACAN.

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ENCLOSURE H

CONTROL OF POSITION, NAVIGATION, AND TIME SYSTEMS IN TIMES OF TENSION OR WAR

1. Introduction. In response to the Federal Aviation Act of 1958, as amended, the Communications Act of 1934, as amended, Executive Order 11490, and the National Security Act of 1947, as amended, NORAD establishes policy and responsibilities for the control of air traffic during emergencies. The decision to execute these emergency procedures for all USG radio-navigation aids resides with the NCA.

2. Security Control of Air Traffic and Navigation Aids. Currently, DOD Instruction 5030.36, April 24,1980, the Security Control of Air Traffic and Navigation Aids (SCATANA) Plan, dictates an emergency preparedness plan that prescribes the joint action to be taken by appropriate elements of the Department of Defense, FAA, and the Federal Communications Commission in the interest of national security to effect control of air traffic and air navigation aids under emergency conditions. DODI 5030.36 is being revised and will include PNT systems such as the FAA's WAAS and the US Coast Guard's maritime DGPS network. The updated plan, when complete, will describe the security control of air traffic (SCAT).

3. Control of Navigation Systems in Times of Tension or War

a. GPS. A military request to change the GPS operating mode or alter the SPS accuracy level will originate with a combatant commander. It will be addressed to the Chairman of the Joint Chiefs of Staff and include the Secretary of Defense and USCINCSPACE as an information addressee. A decision to degrade SPS accuracy or change the GPS operating mode must be approved by the NCA. If time and circumstances permit, the Department of Defense will consult with the Secretary of Transportation. Civil users will be notified via the NOTAM and notice to mariners systems.

b. The SCATANA policy authorizes, under dire emergency conditions, the NORAD region commander to direct turnoff of short-range air navigation aids that, in the commander's judgment, provide more benefit to enemy forces than US forces.

(1) WAAS. The FAA's WAAS is designed with a military emergency mode. When activated, the WAAS services will augment GPS services with capabilities limited to satisfying requirements limited to en route through nonprecision approach. As a USG-provided GPS augmentation, WAAS will be controlled through agreements between the Department of Defense and FAA.

(2) DGPS/NDGPS. Exercising selective control of the USCG's maritime DGPS and the expanding Nationwide Differential GPS System (NDGPS) will be made by NCA based on recommendations from the CINCs and Chairman of the Joint Chiefs of Staff. As USG-provided GPS augmentations, they are controlled through agreements between the Department of Defense and USCG.

(3) LORAN-C. The decision to turn off LORAN-C transmitters is made by NCA based on recommendations from the CINCs and Chairman of the Joint Chiefs of Staff. As a USG standalone radio-navigation system, it is controlled through agreements between the Department of Defense and USCG.

ENCLOSURE I

GEOSPATIAL INFORMATION AND SERVICES

1. Purpose. This enclosure describes, in general terms, the capability and limitations of geospatial information and service (GI&S) products and their relationship with GPS.

2. Background

a. GI&S products, in some form, have been an integral part of every navigation system and must be linked by a common reference system. Historically, horizontal and vertical reference systems have been determined independent of one another. Horizontal reference systems have usually been local or regional and nongeocentric. Vertical positions have been referenced to an equipotential surface that approximated mean sea level.

b. With the advent of satellite positioning systems, it is possible to determine 3D coordinates related to a common geocentric reference. The common reference system used by GPS is the DOD World Geodetic System 1984 (WGS 84). NIMA provided the defining WGS 84 parameters as well as datum shift constants, coordinate transformation formulas, gravity potential coefficients, and a geoid height model. NIMA, as the lead agency for all DOD geodetic reference systems and GI&S products, is responsible for ensuring continuous compatibility with GI&S products.

3. Accuracy Objectives. The accuracy requirements approved by the Chairman of the Joint Chiefs of Staff impose rather stringent positional accuracy demands on both navigation systems and GI&S products used for mission planning, rehearsal, and execution. All GI&S products do not exhibit the same level of absolute and relative accuracy. Some products such as the Digital Point Positioning Data Base (DPPDB) are designed to support the demanding accuracy requirement of precision-guided munitions, while topographic maps serve a different purpose. Users must choose the appropriate set of GI&S products that support their mission objectives.

a. Absolute accuracy of maps and charts is dependent on the accuracy of the geodetic control network upon which those maps and charts are based. The most commonly used maps, the 1:50,000 scale maps, are generally built to a 50-m (Cat II/B), 90-percent circular probability standard, relative to ground control.

b. Although maps and charts are traditional GI&S navigation support products, other GI&S products, such as DPPDB, digital aeronautical flight information files, digital terrain elevation, and digital feature data, also provide required geodetic positions. A photogrammetrically derived point positioning data base used with a system, such as the analytical photogrammetric positioning system, can provide precise position and elevation. To enable Joint Vision 2010, more accurate digital products are necessary.

4. Worldwide Positioning

a. The World Geodetic System 1984 (WGS 84) provides a common accessible global reference frame for DOD operations. NIMA GI&S products and other geospatial data generated within the Department of Defense use WGS 84 to the maximum extent possible as the global framework (datum) for these products and all DOD operations. This geocentric reference frame uses the center of mass of the Earth as the origin and closely follows international conventions regarding the scale and orientation of the reference frame axes.

b. For many reasons, global geocentric reference frames, such as WGS 84, have been adopted rapidly in disciplines such as geodynamics, geodesy, and satellite operations. In contrast, some mapping organizations around the world must deal with the labor-intensive process associated with conversion of existing maps to a modern geocentric reference frame (datum). Many existing maps and nautical charts were created with legacy processes that typically used non-geocentric, regional geodetic datums that differ from WGS 84, in some cases, by several hundred meters.

c. To allow use of these older mapping products generated on regional datums, transformation parameters have been developed that allow a cartographer or other user to convert geospatial data represented on a regional geodetic datum to WGS 84. Note, however, the majority of available geodetic transformations exhibit uncertainties in a range between 3 and 25 meters in each of its translation parameters. This level of accuracy may be adequate for some mapping applications, but a significant amount of care must be exercised before a datum transformation is used in an application that requires a specific level of geospatial accuracy. In some cases, datum transformations may not be available.

d. The universal adoption of a modern geocentric reference frame, such as WGS 84, is a long-term goal shared by many mapping organizations. Until this goal is achieved, a need for these datum transformations will persist and users must be aware of the accuracy limitations associated with the datum transformation process.

e. The WGS 84 is consistent within its precision with the International Terrestrial Reference Frame maintained as the international standard by the International Earth Rotation Service.

5. GI&S Data Acquisition. The implementation of GPS has greatly expanded the GI&S positioning capability by providing a means by which worldwide geodetic control networks can be developed. The increased density of geodetic control allowed by GPS can be used to improve target and fix-point data bases to meet expected weapon system requirements.

6. Products. It is probable that use of graphic products in support of present navigation systems will be largely replaced in future systems by the use of digital GI&S data. As systems are developed, digital (and other) GI&S requirements should be addressed as early in the process as possible to ensure that GI&S support will be available when the system is implemented. Users will continue to require graphics to maintain orientation in case of system failure or to predict a passage between digitally recorded points. The requirements for graphics will continue to be satisfied by conventional graphics, grid-rectified photos and photomosaics, gridded photos, or other forms of visual representation that portray position in terms of the navigation system coordinate readout.

7. Artillery Point Positioning. Target area accuracies available with the GPS will expand the GI&S capability to provide timely, sufficiently accurate positional information necessary to support artillery. Artillery positional requirements exist for firing batteries, countermortar radars, other target location sensors, and forward observers.

8. Bathymetry. Another application of the GPS as a GI&S resource is in the collection of bathymetric data. Initial surveying of bathymetric features requires the use of an accurate navigation system, preferably one with a continuous fix capability. If continuous fixes are not available, the accuracy of bathymetric data acquired may be greatly degraded. GPS will permit fast, accurate positioning of bathymetric features by survey ships in all ocean areas.

9. Multisensor Aerial Mapping. It is expected that GPS will provide an airborne sensor platform with a horizontal positioning accuracy that meets the error allowed for production of large-scale topographic maps. This accuracy level can currently be met only by using electronic navigation systems that have a limited range. The difficulty of moving and operating the stations that support these navigation systems limits efficiency and potential area coverage. GPS will extend these accuracies worldwide, greatly increasing the DOD aerial mapping capability.

10. Limitations of Traditional GI&S Products. Traditional paper products (maps and charts) are not intended to be used for precise positioning and cannot give accurate positions no matter how carefully features are measured. The scale of the product, the survey control methods used, the mapmaking standards applied, and the symbolization of features all limit the possible accuracy attainable for the product.

Although digital products made directly from imagery sources are still not perfect and are affected by production standards applied, they eliminate the other errors noted above and provide the most accurate positions.

11. Future Product Needs. As more sophisticated uses of GPS are developed, more stringent requirements are being levied on GPS system performance. These higher accuracy needs of GPS will require GI&S products such as improved satellite modeling, enhanced WGS 84 Earth gravity models, and more precise geodetic control. GPS is key to providing enhanced absolute accuracy for weapons, improved relative and absolute positioning and significantly reduced mission planning time. NIMA continues to develop methods and techniques to provide timely, relevant, and accurate GI&S products that support Joint Vision 2010 and other national security objectives.

ENCLOSURE J

PRECISE TIME AND TIME INTERVAL

1. Introduction. Timing services, with various degrees of precision, are required by numerous systems and in support of many critical missions. Radio electronic navigation, secure communications, electronic surveillance, improved identification, collision avoidance, formation flight, air traffic control, missile operations, satellite geodesy, and sun-tracking systems are examples of systems and missions that use precise clock time and frequency synchronization. This enclosure discusses PTTI and the importance to military operations.

2. Responsibilities. The USNO, Washington, D.C., is the agency responsible for PTTI reference values for all Services, agencies, contractors, and related scientific laboratories, coordinating DOD timing capabilities, analysis, evaluation, and monitoring of R&D and operational PTTI systems. The USNO accomplishes its mission by maintaining a timing facility in Washington, D.C., and an alternate master clock facility, designated US Naval Observatory Alternate Master Clock (USNO AMC), at Schriever Air Force Base.

3. Requirements

a. Most timing requirements are based on a need for synchronization or coordination among cooperating units of a system or between systems. Although synchronization is maintained internally in some systems, others must acquire synchronization independently before participating in system activities. For these and systems that must operate with other precisely timed systems, a common, accessible standard is needed. The standard for military systems is UTC as maintained by the USNO Master Clock. This UTC (USNO) is the real-time realization of UTC as determined by the Bureau International des Poids et Mesures, Sevres, France. The contribution of UTC (USNO) to the international time scale is approximately 40 percent. The difference between the time scales is less than 25 nanoseconds (ns).

b. Time accuracy is the degree to which UTC (USNO) is known or maintained by systems requiring interoperability. It is affected both by onboard timekeeping ability and the accuracy with which the onboard clocks can be periodically updated through UTC (USNO) dissemination services. Therefore, UTC (USNO) dissemination accuracies generally must exceed the stated onboard time accuracy requirements. Most military electronic systems require a precise and accurate common time -- the reference time as established by the USNO. Accuracy requirements vary among systems, but whether the requirement is in terms of minutes or nanoseconds, a means of referring system clocks to the DOD time reference is necessary.

c. Uses of a precise uniform time scale include power and communication utilities, navigation, targeting, guidance, and research. Timing accuracy requirements vary widely depending on the nature of each use. Celestial navigation requires timing accuracy of 0.1 second (1 sigma). One to 100 milliseconds (1 sigma) are required for wide area computer networks, and fast networks require microsecond accuracy. One hundred microseconds (1 sigma) are required for some geodetic and geophysical applications, missile technology, and satellite observations. One-sigma accuracies ranging from minutes to 5 nanoseconds or less (synchronized clock time) are required for Department of Defense applications today. LORAN-C master transmitters were directed by Public Law 100-223 to be within 100 nanoseconds of UTC (USNO). Specific time and frequency requirements for other radio-navigation systems may be obtained from the USNO. Precise time can be considered a utility with virtually the entire population being affected by some degree of timing requirement.

d. Astronomical time (UT1) of 100-microsecond accuracy is provided by USNO to users requiring access to inertial reference frames for targeting, satellite orbit determination, navigation, and geodetic applications. There are several thousand military and civilian users having this requirement.

e. Five nanoseconds (1-sigma accuracy) synchronized clock time is currently (1999) the most stringent timing requirement for Department of Defense operational applications. Research applications require timing at the subnanosecond level, and even greater accuracy requirements are expected for advanced space research, radio astronomy, and testing and development of advanced time systems.

4. Current Operations. Users may acquire precise time information to address their requirements from a variety of sources that are traceable to USNO. Figure J-1 highlights some commonly used techniques.

		RMS Precision		RMS Accuracy
System	Mode	Normal	Best	
LORAN-C	Passive	100 ns	50 ns	100 ns
GPS keyed	Passive	10 ns	6 ns	20 ns
GPS Common View	Active	10 ns	4 ns	20 ns
TWSTT	Active	200 ps	200 ps	1 ns
Voice Announcer	Active	1 s	.5 s	1 s
Modem	Active	5 ms	1 ms	5 ms
NTP	Active	4 ms	1 ms	4 ms

Figure J-1. Systems Distributing UTC (USNO)

Methods of receiving PTTI are described below:

a. The USNO provides certification of clocks or times involved in time dissemination, weapons integration, surveillance, countermeasure systems coordination, and satellite control. This certification is accomplished by providing documentation of traceability to UTC (USNO).

b. USN VLF stations, LORAN-C chains operated by the USCG that have special-timing capability, and GPS provide PTTI with varying degrees of accuracy. GPS provides SPS users time with an accuracy of 80 nanoseconds (2 sigma) and PPS users with a much greater accuracy. GPS is the most readily available system to obtain high-accuracy PTTI information.

c. All National Institute of Standards and Technology (NIST) time signal transmissions and some selected foreign transmissions are being monitored in order to make precision corrections available to users and to radio distribution services. This monitoring procedure permits the reference of time signals to any of the major time scales in use including astronomical time, UTC, and GPS time.

d. Radio broadcast of time signals (coded or plain language time information) are available from the NIST stations WWV, WWVH, and WWVB, a system funded by the Department of Commerce. Time signals are synchronized with the USNO Master Clock to within 1 microsecond. The accuracy of signals received beyond line of sight from the stations (with nominal correction for the ionosphere and propagated signal path) is on the order of 1 millisecond.

e. TWSTT is available from USNO for high-precision PTTI. This procedure makes use of geostationary communication satellites to transfer time. The level of accuracy depends on the user's situation. If the user's geodetic position is known and the TWSTT system is calibrated, 1-nanosecond time transfer is possible. Accuracy is degraded when the user's position is poorly determined or the receiving system is uncalibrated.

f. DSCS stations maintain precise time traceable to the USNO Master Clock, and the system serves as a trunk line to provide precise time to certain other facilities. Time comparisons made through the system are operationally accurate to 0.1 microsecond and have the capability of providing time accuracy of 10 to 50 nanoseconds.

g. The USNO provides a voice time announcement and time ticks (accurate to the millisecond level if propagation delays are known from a previous measurement). See Figures J-2 and J-3.

TELEPHONE VOICE TIME ANNOUNCER	**TELEPHONE TIME FOR COMPUTERS**	**TIME OVER THE INTERNET and SIPRNET**
(202) 762-1401 DSN 762-1401	(202) 762-1594 DSN 762-1594 1200 Baud, No Parity, 8 Bit **Available Software** Timeset (360) 387-9788 CallTime (518) 477-4934 PCClock 75046.2272@compuserv.com RightTime (214) 402-9660 Accuset 70254.2017@compuserv.com	**Via** **Network Time** **Protocol** tycho.usno.navy.mil/ntp.html

Figure J-2. Sources of USNO Time

DATA VIA MODEM (USNO ADS)	**DATA OVER THE INTERNET**
(202) 762-1602 (202) 762-1610 (202) 762-1503 1200 - 14400 Baud No Parity 8 Bit	via Telnet: tycho.usno.navy.mil Login: ads via World Wide Web http://tycho.usno.navy.mil via Anonymous FTP: tycho.usno.navy.mil Login: anonymous Password: your e-mail address Automated e-mail Server Send mail to adsmail@tycho.usno.navy.mil with Subject: index

Figure J-3. Sources of USNO Information and Data

h. The USNO provides computer network time synchronization service meeting Internet standard RFC-1305 NTP. USNO NTP servers provide UTC (USNO) with millisecond accuracy over wide area networks, including the unclassified (but sensitive) Internet Protocol Routing Network (NIPRNET) and Secret Internet Protocol Routing Network (SIPRNET). Servers are geographically dispersed to minimize network delay and distribute traffic.

5. Other Issues

a. NATO has produced a Military Operational Requirement for the Provision of Precise Time (MMC-SFM-081-93) dated 28 July 1993. This document has three main provisions: (1) the adoption of an agreed source as precision time reference; (2) the dissemination of the time reference; and (3) the acquisition and maintenance of the precise time reference with the appropriate level of accuracy. The reference was approved as UTC, but the other provisions will require the definition of an architecture of how the various systems will interoperate and maintain the accuracies necessary for the different users and systems requirements.

b. GPS is the primary source of PTTI for operational forces. The interface between USNO and GPS is specified by the interface control document ICD-GPS-202 that states that GPS time must be maintained within 1 microsecond of UTC (USNO). There is a further requirement that the transmitted correction to UTC must be within 28 ns (1 sigma). Historical data has shown that GPS time has been within 100 ns of UTC (USNO), and the correction to UTC (USNO) has been well within 20 ns. Because the epoch of GPS time differs from UTC, there are an integral number of seconds between the two.

c. The US Navy continues to upgrade the Master Clock System at the USNO to achieve an order of magnitude improvement to one part in 10 to the 15th. This time reference system will be used for both current and projected user systems with PTTI requirements that exceed current capabilities; e.g., GPS.

6. Precise Time Stations. A plan for a Distributed Master Clock is being developed in the event that the USNO may become incapacitated and to meet future requirements not anticipated to be met by GPS. The Distributed Master Clock will consist of Precise Time Stations, having a reference clock traceable to UTC (USNO). The nucleus of this Distributed Master Clock is the USNO AMCS located at Schriever AFB, Colorado. The UTC (USNO) dissemination functions will be transferred automatically from Washington, D.C. to Colorado as required.

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ENCLOSURE K

REFERENCES

a. CJCSI 3170.01, 10 August 1999, "Requirements Generation System"

b. DOD Directive 4650.5, 5 December 1990, "Positioning and Navigation Systems Administration and Planning"

c. DOT-VNTSC-RSPA-97-2/DOD-4650-5, "1998 Federal Radionavigation Plan"

d. "Global Positioning System Standard Positioning Service Signal Specification," 2 June 1995, 2d Edition

e. "Department of Defense Global Positioning System (GPS) Security Policy," 29 March 1999

f. US Global Positioning System Policy, Presidential Decision Directive, (PDD) NSTC-6, 28 March 1996

g. CJCSI 6140.01, 15 November 1998, "NAVSTAR Global Positioning System Selective Availability Anti-Spoofing Module Requirements"

h. CJCSI 3010.01, 10 October 1996, "Chairman's Joint Vision 2010 Implementation Policy"

i. Deputy Secretary of Defense memorandum, 8 September 1998, "Positioning, Navigation, and Timing"

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GLOSSARY

1D	one dimensional
2D	two dimensional
3D	three dimensional
ACLS+	automatic carrier landing system plus
ACN	advanced celestial navigator
ADS	automatic dependent surveillance
AEP	Architecture Evolution Plan
AFRL	Air Force Research Laboratory
AFSCN	Air Force Satellite Control Network
AHRS	attitude heading reference system
AMCS	Alternate Master Control Station
AOA	analysis of alternatives
ARINC	Aeronautical Radio Incorporated
ARTS	AFSCN remote tracking stations
A-S	anti-spoof (GPS)
ASD	Assistant Secretary of Defense
ASD(C3I)	Assistant Secretary of Defense for Command, Control, Communications, and Intelligence
ASPARCS	air surveillance and precision approach radar control system
ASR	air surveillance radar
ATC	air traffic control
ATCRBS	air traffic control radar beacon system
ATM	air traffic management
C/A code	Coarse/Acquisition code (GPS)
C2	command and control
C3	command, control, and communications
C3I	command, control, communications, and intelligence
CAINS	carrier aircraft inertial navigation system
CCW	continuous carrier wave
CG	cruiser
CGN	nuclear-powered cruiser
CINC	commander of a combatant command; commander in chief
CJCS	Chairman, Joint Chiefs of Staff
CNS	communications, navigation, surveillance
CNS-ATM	communications, navigation, surveillance -- air traffic management
CPC	CSEL planning computer
CRAF	Civil Reserve Air Fleet
CRPA	controlled reception pattern antenna
crypto	cryptographic
C-SCAN	carrier system for controlled approach of naval aircraft

CSEL	Combat survivor evader locator
CVNS	aircraft carrier navigation systems
DAGR	defense advanced GPS receiver
dB	decibel
DD	destroyer
DDG	guided-missile destroyer
DF	direction finding
DGPS	Differential Global Positioning System
DII COE	Defense Information Infrastructure Common Operating Environment
DISA	Defense Information Systems Agency
DME	distance measuring equipment
DNSO	Defense Network Systems Organization
DOT	Department of Transportation
DPPDB	digital point positioning data base
drms	distance root-mean-square
DSCS	defense satellite communications systems
DSMAC	digital scene matching area correlation
DSN	Defense Switched Network -- DOD voice telephone net (formerly AUTOVON)
DSP	digital signal processing
ECCM	electronic counter-countermeasures
ECDIS-N	Electronic chart display and information system -- US Navy
EMP	electromagnetic pulse
ESG	electrostatic-supported gyro
ESGN	electrically suspended gyro-navigation
FAA	Federal Aviation Administration
FAME	full-sky astrometric explorer
FDDI	fiber distributed data interface
FIST-V	artillery fire support team vehicles
FMS	foreign military sales
FRP	Federal Radio-Navigation Plan
FRPA	fixed-radiation pattern antenna
FY	fiscal year
GaAs	gallium arsenide
GAs	ground antennas
GATM	global air traffic management
GCA	ground-controlled approach
GCA/PAR	ground-controlled approach/precision approach radar
GHz	gigahertz
GI&S	geospatial information and services

GPS	Global Positioning System
GYROS	gyroscope
HHR	hand-held radio
HIFOG	high-accuracy fiber-optic gyro
Hr	hour
Hz	hertz
IATCS	identification and air traffic control systems
ICAO	International Civil Aviation Organization
ICLS	instrument carrier landing system
IFCS	improved fire-control system
IFF	identification, friend or foe
IFW	indirect fire weapons
IGEB	Interagency GPS Executive Board
ILS	instrument landing system
IMO	International Maritime Organization
IMU	inertial measuring unit
INS	inertial navigation system
JPALS	joint precision approach and landing system
JPO	Joint Program Office (GPS)
JROC	Joint Requirements Oversight Council
J-STARS	joint surveillance, target attack radar system
JTIDS	joint tactical information distribution system
kHz	kilohertz
km	kilometer
KPP	key performance parameter
kW	kilowatt
LAAS	local area augmentation system
LAN	local area network
LDGPS	Local Area Differential Global Positioning Systems
LF	low frequency
LHA	general purpose amphibious assault ship
LHD	general-purpose amphibious assault ship (with internal dock)
LOP	line of position
LORAN	long-range navigation
LORAN-C	C version of LORAN
LPD	low probability of detection
LPI	low probability of intercept
m	meters
MAPS	modular azimuth positioning system

MATCALS	Marine air traffic control and landing system
MCS	master control station (GPS)
MCW	modulated continuous wave
MF	medium frequency
MHz	megahertz
MIDS	multinational information distribution systems
MLS	microwave landing system
MMLS	mobile microwave landing system
MMR	multimode receiver
MNP	Master Navigation Plan
MNS	mission need statement
MOA	memorandum of agreement
MPNTP	Master Positioning, Navigation, and Timing Plan
MRAALS	Marine remote area approach and landing system
MS	monitor station
MSS	mobile satellite system
NAS	national airspace system
NATO	North Atlantic Treaty Organization
NCA	National Command Authorities
NDB	nondirectional beacon
NDGPS	Nationwide Differential Global Positioning System
NIMA	National Imagery and Mapping Agency
NIPRNET	unclassified (but sensitive) Internet Protocol Routing Network
NIST	National Institute of Standards and Technology
nm	nautical miles
NORAD	North American Aerospace Defense Command
NOTAM	notice to airmen
NRL	Naval Research Laboratory
ns	nanoseconds
NSA	National Security Agency
NSG	north seeking gyro
NTP	network time protocol
OASD(C3I)	Office of the Assistant Secretary of Defense (Command, Control, Communications, and Intelligence)
ORD	operational requirements document
OSD	Office of the Secretary of Defense
OTAR	over-the-air rekey
OTH	over the horizon
PADS	position azimuth determining system
PALC	precision approach and landing capability
PALS	precision approach landing system
PAR	precision approach radar

PDD	Presidential Decision Directive
PDOP	position dilution of precision
PDS	position determining system
PE	probable error
PLGR	precise lightweight GPS receiver
PLSR	precision landing system receiver
PNT	position, navigation and time
POM	program objective memorandum
PPS	Precise Positioning Service (GPS)
PRN	pseudo-random noise
PTTI	precise time and time interval
PVT	position, velocity, and time
P(Y)	precise code (encrypted)
R&D	research and development
RAPCON	radar approach control
RLG	ring laser gyro
RLGN	ring laser gyro navigator
rms	root-mean-square
RNP	required navigation performance
RSA	radio set adapter
rss	root-sum-squared
SA	selective availability (GPS)
SA/A-S	selective availability/anti-spoof
SAASM	Selective Availability/Anti-Spoof Module
SARPS	standards and recommended practices
SARSAT	Search and Rescue Satellite Aided Tracking
SATCOM	satellite communications
SCATANA	security control of air traffic and navigation aids
SCAT	security control of air traffic
sec	second
SEP	spherical error probable
SIAGL	survey instrument azimuth gyroscope lightweight
sigma	standard deviation
SIPRNET	Secret Internet Protocol Routing Network
SIS	signal in space
SONAR	sound navigation ranging
SPS	Standard Positioning Service (GPS)
SRP/PDS	stabilization reference package/position determining system
SSBN	nuclear-powered fleet ballistic submarine
SSN	nuclear-powered attack submarine
STELLA	system to estimate latitude and longitude astronomically
TACAN	tactical air navigation

TCP/IP	Telecommunications Control Protocol/Internet Protocol
TERCOM	terrain contour matching
TSO	technical standard orders
TWSTT	two-way satellite time transfer
UBS	UHF base stations
UE	user equipment
UHF	ultrahigh frequency
USA	US Army
USAF	US Air Force
USCG	US Coast Guard
USCINCSPACE	Commander in Chief, US Space Command
USCINCSTRAT	Commander in Chief, US Strategic Command
USD(AT&L)	Under Secretary of Defense (Acquisition, Technology & Logistics)
USG	US government
USMC	US Marine Corps
USN	US Navy
USNO	US Naval Observatory
USNO AMC	US Naval Observatory Alternate Master Clock
USSPACECOM	United States Space Command
UT1	universal time determined from the Earth's rotation
UTC	coordinated universal time
UTM	universal transverse mercator
VHF	very high frequency
VLF	very low frequency
VOR	very high frequency omnidirectional range station
VORTAC	combined VOR/TACAN station
WAAS	wide area augmentation system (GPS)
WGS 84	World Geodetic System 1984
WRC	World Radio Council
WWV	call letters for radio stations broadcasting time signals
WWVB	call letters for radio stations broadcasting time signals
WWVH	call letters for radio stations broadcasting time signals
Y code	precise code (GPS)