ALLIED NAVIGATION PUBLICATION **ANP-4**
Edition 1

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THE NATO GUIDELINE FOR MEMBER STATE CERTIFICATION OF IFR NAVIGATION SYSTEMS USING GPS PPS

The information contained in this document shall not be released to a nation outside NATO without following procedures contained in C-M(2002)60

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NORTH ATLANTIC TREATY ORGANIZATION

NATO STANDARDIZATION AGENCY (NSA)

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23 February 2007

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FOREWORD

Increasing air traffic and airspace density are putting escalating pressure on military traffic operating and navigating in both civil and military controlled (area of operation) airspace. It must be assured military (or state) aircraft transiting civil controlled airspace causes minimal disturbance to the civil aircraft and operations in that airspace.

State and military aircraft have particular needs and limitations arising from their mission profile and aircraft types. To ensure continued access to civil-controlled airspace for all military and state aircraft, Nations will be increasingly required to conduct flights under General Air Traffic rules rather than Operational Air Traffic rules.

In peace time, the rules and procedures of the General Air Traffic and the Air Traffic Management (ATM) with respect of Communication, Navigation, and Surveillance (CNS) should be followed as much as possible by the military aviation community.

Article 3 of the International Civil Aviation Organization (ICAO Chicago Convention) provides guidance with respect to the distinctions between and operations of state and civil aircraft. Specifically, it states:

Article 3 Civil and state aircraft
(a) This Convention shall be applicable only to civil aircraft, and shall not be applicable to state aircraft.
(b) Aircraft used in military, customs and police services shall be deemed to be state aircraft.
(c) No state aircraft of a contracting State shall fly over the territory of another State or land thereon without authorization by special agreement or otherwise, and in accordance with the terms thereof.
(d) The contracting States undertake, when issuing regulations for their state aircraft, that they will have due regard for the safety of navigation of civil aircraft.

NATO understands the benefit of CNS/ATM developments on military aviation. IFR certification of Navigation Systems using GPS PPS is one part of this program. This Allied Navigation Publication (ANP) was written under a common understanding of civil and acceptance of military aviation authorities of the NATO members, each recognizing the other's individual responsibility to certify their own fleet.

It is the common goal to ensure a safe and efficient co-existence of civil and military air navigation activities within the same domestic and international airspace.

The ANP-4 can be used as a guideline to help individual military authorities to certify their Navigation Systems for IFR when using the PPS GPS.

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CHAPTER 1. EXECUTIVE SUMMARY

101 Introduction

Navigation in civil airspace is facing new challenges. As air traffic grows constantly, the separation between aircraft must be drastically reduced, hence requiring higher performances of the navigation systems.

The International civil aviation is pursuing three major initiatives to modernize air navigation:

1. Required Navigation Performance (RNP).
2. Exploitation of the capabilities of satellite navigation under the rubric of "Global Navigation Satellite System" (GNSS).
3. Enhancement of Area Navigation (RNAV) based on RNP compliant aircraft.

These three air navigation initiatives join together with other aviation programs to enable a new paradigm – one of the most popular being “Communications, Navigation, Surveillance / Air Traffic Management” (CNS/ATM).

One of the main revolutions that will come from these initiatives is that the requirement will no longer be hardware based (mandatory equipage) but performance based.

102 Certification processes

The certification process for civil aircraft is well established. The process relies on national CAA efforts, but the standardization of rules/regulations and airworthiness codes, that are under the auspices of the ICAO, facilitate the international traffic of aircraft. The multilateral agreements and mutual recognition avoid repeating the same lengthy and costly process for each country where an aircraft is supposed to fly.

Within the international civil aviation community there are two sets of documentation for rules and regulations. One is under the responsibility of the US FAA, the other one is under the responsibility of the European EASA. However, even if the documents in each organization have different references, the rules and regulations for the use of the GPS SPS in IFR are identical.

The TSO-C129() (FAA) and the CSETSO-C129() (EASA) authorize, under certain conditions, the use of GPS SPS as supplemental means of navigation of the flight phases up to NPA.

The TSO-C145() and CS-ETSO-C145() regulates the use of GPS SPS plus WAAS, under certain conditions, as a primary means of navigation for flight phases up to NPA.

Military aircraft are considered as state aircraft by the ICAO Chicago Convention. As such they have a very different treatment (see article 3 of the convention)

- They are not under the scope of the Chicago Convention
- International flights are subject to bilateral agreements or authorizations
- The originating states are responsible for the qualification of their state aircraft

In each nation, the national MoD is generally responsible for the certification/qualification of their aircraft.

103 Use of the GPS PPS

For obvious operational reasons, the military platforms use GPS PPS instead of GPS SPS.
Compared to GPS SPS, the GPS PPS is indeed more accurate and has more resistance to Navigation Warfare (Navwar).

Although GPS PPS equipment is more resistant to jamming, no credit is being taken for the superior performance. Credit is only being taken for GPS PPS equipment being at least as good as GPS SPS equipment when operated in the civil interference environment specified in the ICAO SARPs.

The key issue is to make these GPS PPS equipment or Navigation systems using the GPS PPS compatible with the new and more stringent airspace requirements. By doing so, it will not be necessary to have two GPS navigation suites inside the aircraft: one for navigation in civil airspace en route to or coming from the area of military operations, the other one for military missions in the combat zone.

To help the qualification of PPS equipment, the US DoD has developed a process to mirror the TSO documents. This process has produced Military Standard Orders (MSO) documents, and the requirements contained in these documents are at the minimum equal to the requirements in the TSO documents. The MSO-C129, MSO-C144 and MSO-C145 have been written to adapt the corresponding TSO documents to the use of GPS PPS.

A GPS PPS signal specification has also been produced providing an official performance statement for the military GPS signal (the PPS Performance Standard).

The Navigation Systems Panel (NSP) of the ICAO has been informed by the US DoD about the MSO process. While state aircraft are outside the scope of ICAO’s responsibility, in the minutes of their October 2004 meeting the NSP recognized there is no need to restrict the operations of GPS PPS equipped aircraft in civil airspace provided they are certified to meet or exceed civil standards.

Military aircraft employ various architectures to overcome the effects of Navwar. Examples of these architectures include antennas that adapt their radiation diagram as a function of the Electronic Counter Measures (ECM) encountered (e.g. Controlled Reception Pattern Antenna (CRPA)) and tightly coupled or deeply integrated GPS PPS and INS systems. These navigation architectures are not currently addressed by ICAO and the certification/qualification of these architectures for flight in civil controlled airspace is being addressed.

104 Recommendations

It is recommended that NATO nations use this document as a baseline reference source for developing national certification/qualification of IFR systems using GPS PPS. To move forward with the authorization of GPS PPS in civil controlled airspace two important steps will be required by NATO and member states.

104.1 *Step 1: Acceptance among NATO nations*

Each NATO nation must analyze if the use of PPS GPS receivers is acceptable within their respective civil airspace and, if acceptable, define the regulatory documentation/procedures for the approval of such avionics. NATO nations also must authorize the use of the GPS PPS SIS for use in sovereign airspace.

104.2 *Step 2: International acceptance*

NATO and NATO nations are encouraged to collaborate through ICAO by providing regulatory documentation/procedure for the use of PPS avionics in order to facilitate bilateral recognition of the use of PPS avionics in civil airspace.

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CHAPTER 2. INTRODUCTION

201 Why Certify the Use of GPS PPS Based Navigation Systems?

The Global Positioning System (GPS) currently enables highly accurate position, velocity and timing information for aircraft navigation and surveillance functions during all phases of flight and surface operations. Basic benefits of GPS to the aviation community include the potential for improved operational performance for all phases of flight and global airspace coverage. These benefits enable the potential for: reduced avionics requirements; improved global navigation; area navigation and the capability to fly optimized routes; and increased instrument approach and departure capabilities to suitable runways and airfields. Additionally, governments may have an opportunity to reduce the costly infrastructure of current ground-based systems dedicated to navigation and surveillance. The benefits of GPS Precise Positioning Service (PPS) allow for the realization of more secure and accurate navigation performance for military and other authorized users.

NOTE: Future GNSS (i.e. Galileo) may also provide similar benefits to the world community as a complement to GPS PPS.

201.1 *Rationale for Use of GPS PPS*

NATO aircraft require highly accurate satellite navigation for successful mission accomplishment. The improved accuracy of GPS PPS, as compared to GPS Standard Positioning Service (SPS), along with its superior jam-resistance and anti-spoofing capability, make its use by NATO aircraft a military necessity. As a result, many NATO aircraft are equipped with GPS PPS receivers.

In many cases, it is cost and space-prohibitive for nations to dual-equip military aircraft with both SPS avionics to transit civil controlled airspace and PPS avionics to accomplish the military mission. The use of GPS PPS as a navigation source in civil controlled airspace will represent a significant milestone for all NATO members who equip with such navigation equipment. If military aircraft equipped with GPS PPS avionics are certified/qualified and authorized to fly under instrument flight rules (IFR) in civil controlled airspace, GPS PPS will allow those aircraft to participate in a seamless air traffic control system across national and international boundaries. In most cases, specifically designed GPS PPS equipment will be required to comply with IFR performance standards.

The level of performance and safety inherent in these aircraft must be assessed and aligned with civil performance capabilities to meet or exceed the airspace requirements. Each NATO country must pursue its own national certification/qualification and authorization process.

Many current and future military aircraft can be evaluated to determine an achievable level of navigation performance to which it can be certified. Host nations must understand and agree that GPS PPS and the associated avionics may be a part of this certification and that GPS PPS performance meets or exceeds that of the GPS Standard Positioning Service (SPS). The International Civil Aviation Organization (ICAO) Navigation Systems Panel recognized there is no need to restrict the operations of GPS PPS equipped aircraft in civil airspace provided they are certified to meet or exceed civil standards, as mentioned in minutes of the *Navigation Systems Panel Report of the Working Group of the Whole Meeting, Montreal, Canada, 12-22 October 2004, paragraph 12.2*. The NSP reached the following conclusions:

> The information paper described the US plans for state aircraft to use GPS PPS in domestic and international airspace. The paper provided a summary and progress update of the US DoD approach for using current and next generation GPS-PPS equipment for RNP-20 through RNP-0.3 RNAV global airspace operations.
>
> It was noted that the US DoD has adopted a rigorous certification process to assure GPS-PPS equipment meets or exceeds all appropriate civil certification requirements. From an operational perspective, it was recognized that it is desirable for all States if military aircraft can operate transparently in a performance-based operational environment.
>
> It was also recognized that the development of common military standards for PPS, and equivalency between those standards and civil standards, would facilitate the goal of transparent operation. Based on the use of these standards, from a navigation perspective there is no need to restrict the operations of military aircraft in civil airspace.
>
> The meeting noted that the key issue with military equipment is the assurance of integrity, not whether the system uses SPS or PPS. It was agreed that there is no operational or practical need to deselect PPS, and there are operational concerns with even providing such a feature.
>
> It was further recognized that there are different approval processes for state and civil aircraft and operations, and that state aircraft are outside the scope of ICAO's responsibility. Recognizing this, it was agreed that compliance to civil requirements through equivalent military standards was desirable.

The successful introduction and acceptance of GPS PPS as part of a navigation solution will be dependent on the co-operation of all users of the airspace.

201.2 *NATO Position*

The NATO C3 Board Navigation Sub-Committee (SC/8) stated in 2003 that guidelines for the use of PPS in civil controlled airspace needed to be established. This Allied Navigation Publication is the result of the member nations jointly examining the requirements for military aircraft to complete their missions, with a focus on transiting civil controlled airspace.

201.3 *ANP Scope*

This document outlines and establishes how GPS PPS could be used in civil controlled airspace. It addresses: (1) Authorizing use of the PPS Signal-in-Space (SIS) in national airspace, and (2) certification/qualification of military aircraft and equipment using PPS. This document does not address database issues. Databases issues are beyond the scope of the document. Database issues are common to both SPS and PPS users. This document also does not address restrictions on hazardous substances, signal simulators, and aircraft level safety analysis.

202 Overview of GNSS Elements

202.1 *Current GNSS Systems*

202.1.1 Global Positioning System (GPS)

Fully operational since 1995, GPS is a Global Navigation Satellite System (GNSS) operated by United States Department of Defense (US DoD). Composed of 24 satellites in Medium Earth Orbit (MEO), GPS provides navigation and timing signals on two carriers at L1 (1575.42 MHz) and L2 (1227.6 MHz). The broadcasting technique is a Code Division Multiple Access (CDMA), which means that all satellites broadcast navigation and timing signals on the same frequencies, but with different spreading codes.

The GPS system provides two services:

- The *Standard Positioning Service* (SPS) is emitted on the L1 frequency only and is open to all users. The SPS has a bandwidth of 2 MHz and is based on the use of the Coarse/Acquisition (C/A) code. There are plans to provide a civil service on L2 in the near future, followed by a third civil service on the Aeronautical Radio Navigation Service (ARNS) protected L5 (117645) band.
- The *Precise Positioning Service* (PPS) is available on L1 and L2 frequencies, has a bandwidth of 20 MHz, and is based on the use of the P-code. The P-code is usually encrypted into the Y-code (or P(Y)-code) and cryptographic materials are necessary to access P(Y)-code.

Only approved users can gain access to the GPS PPS. All NATO nations have continuous access to the GPS PPS under the umbrella of the Memorandum of Understanding (MOU) IV and its addenda. The US has also granted access of GPS PPS to other allied nations.

202.1.2 GPS Augmentation Systems

To enhance the performance of GPS SPS, augmentation systems have been and are being developed. Types of augmentations are categorized by ICAO Standards and Recommended Practices (SARPs) based on the platform used as Satellite/Space Based Augmentation Systems (SBAS), Ground Based Augmentations Systems (GBAS), and Aircraft Based Augmentation Systems (ABAS).

- SBASs are provided through Geostationary Earth Orbit (GEO) satellites and a network of ground stations monitoring the GPS-SPS, determining and transmitting signal corrections. These types of augmentations are categorized as regional augmentations systems. The SBAS satellites broadcast on the same carrier frequency as the SPS (frequency L1).
- GBASs rely on a ground station carefully monitoring the navigation signals and provide a higher level of accuracy and integrity than the wide area augmentations. Local augmentations provide data via VHF data links.
- ABASs augment and or integrate the information obtained from GNSS elements with information available on board the aircraft to insure integrity and accuracy. ABASs include processing schemes which provide integrity monitoring for the position solution using redundant information (e.g. Receiver Autonomous Integrity Monitoring (RAIM) algorithms) and continuity aiding using information from alternative sources like INS, barometric altimetry, and external clocks.

SBAS with associated ICAO SARPs:

- Wide Area Augmentation System (WAAS): WAAS provides corrections over the USA and Canada. It relies on geostationary satellites (currently provided by INMARSAT) to relay the corrections. WAAS was developed and operated by the US Federal Aviation Administration (FAA). The Initial Operational Capability (IOC) was established in 2003.
- European Geostationary Navigation Overlay Service (EGNOS): EGNOS provides corrections over Europe and relies on GEO satellites. EGNOS is a project of the European Commission (EC), the European Space Agency (ESA) and EUROCONTROL. The IOC of EGNOS occurred in July 2005.
- MTSAT Satellite Augmentation System (MSAS): MSAS provides corrections over Japan and is based on the use of two general-purpose Ministry of Transport Satellites (MTSAT); After the failure of the first launch in 1999, The satellite MTSAT-1R has been launched and placed in orbit in Feb 2005. It should start its operational phase in 2006. The launch of a second satellite (MTSAT-2) is scheduled for 2006.

Future augmentations:

- Ground-based Regional Augmentation System (GRAS): GRAS is based on a network of GRAS reference stations monitoring the GNSS signals across Australia and sending this information to a GRAS Master Station. The GMS calculates the corrections and send them to GRAS VHF Stations. The GVS sends GBAS like information to the user equipments in aircraft. ICAO is developing SARPs for the GRAS.
- Local Area Augmentation System (LAAS): This GBAS uses a system of reference GPS receivers, exacting siting criteria and sophisticated software located at select airports to

determine precise corrections needed for lateral and vertical guidance to achieve CAT I, II & III minima. These corrections are broadcast over a VHF data link.

- Joint Precision Approach and Landing System (JPALS): This system is being developed by the US DoD to provide a PPS GBAS service for land based airfields and ship based platforms. It broadcasts PPS correction signals over a UHF data link (2-way data link for sea-based applications) and will be compatible with LAAS.

202.1.3 Global Navigation Satellite System (GLONASS)

Fully Operational in 1995, the GLONASS system is operated by the Russian Ministry Of Defense. GLONASS is composed of 24 MEO satellites. The broadcasting technique is a Frequency Division Multiple Access (FDMA), which means that each satellite broadcasts on a separate frequency, with the same codes. Broadcasts begin at 1602 MHz and satellite broadcast frequencies are “increased” by 1602 MHz + n0.5625 MHz, where “n” is the frequency channel number (n=0,1,2…).

The Standard Precision service is open to all users.

The High Precision service was intended to be used by military forces, but the encryption scheme has not yet been implemented, therefore it is currently available to all users.

The GLONASS system does not currently provide global coverage. Sixteen satellites are operational as of September 2006.

202.2 *Future Systems*

NOTE: the below systems have officially declared their candidacy for SARPs development.

202.2.1 Galileo System

The Galileo system is a project of the European Commission (EC) and European Space Agency (ESA). Galileo will provide four satellite navigation services at several frequencies described below.

- The Open Service for all users will use a Binary Offset Carrier (BOC) signal in L1 and a signal in E5a and E5b (1164-1215 MHz).
- The Commercial Service with enhanced features is for authorized users paying a fee. This service will use two signals in the E6 band (1260-1300 MHz), plus the open service.
- The Safety-of-Life (SOL) service is dedicated to applications such as civil aviation or maritime navigation. The service will be available at the same frequencies as the open service.
- The Public Regulated Service (PRS) is designed with a controlled access for governmental applications. The PRS will use two BOC signals, one in L1 and one in E6. The precise definition of the PRS signal is not yet fully completed.

The first Galileo satellite was launched on December 28th, 2005 and started emitting Galileo signals on January 12th, 2006.

202.2.2 Indian GAGAN (GPS SBAS)

The GPS Aided GEO Augmented Navigation (GAGAN) satellite navigation system is an SBAS system over India. It will broadcast signals from GEO satellites over the India region to provide a higher accuracy/integrity for civil aviation.

CHAPTER 3. BACKGROUND

ICAO is pursuing three major initiatives to modernize air navigation:

1. Required Navigation Performance (RNP).
2. Exploitation of the capabilities of satellite navigation under the rubric of "Global Navigation Satellite System" (GNSS).
3. Enhancement of Area Navigation (RNAV) based on RNP compliant aircraft.

These three air navigation initiatives join together to provide a more robust Communications, Navigation, Surveillance / Air Traffic Management (CNS/ATM) system.

Required Navigation Performance (RNP) is an ICAO term that originated in 1990. Specifically, RNP is a numerical parameter describing lateral deviations from assigned or selected track as well as along track position fixing accuracy on the basis of an appropriate containment level. The concept of "RNP is a statement of the navigation performance necessary for operations within a defined airspace"[ICAO Doc. 9613]. RNP types are identified by a single accuracy value calculated at the 95% probability level, for instance RNP-4. For an aircraft to operate in RNP-4 airspace, the navigation performance of the aircraft must be at least 4 nautical miles (nm) or better at the 95% probability level. This performance accuracy value (i.e. 4 nm) is based on a combination of the navigation sensor error, airborne receiver error, display error and flight technical error.

Global Navigation Satellite System (GNSS) is a generic ICAO term intended to describe satellite-based navigation systems. Core GNSS elements include the Global Positioning System (GPS) provided by the U.S. and GLONASS provided by the Russian Federation. Galileo is a potential future core system that is being developed by the EU.

Area Navigation (RNAV) is “a method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids, or within the limits of the capability of self-contained aids, or a combination of these.” [RTCA/DO 236B]. The overall safety of an RNAV operation is achieved through a combined use of aircraft navigation accuracy, route spacing and/or air traffic control interventions (e.g. via radar monitoring, Automatic Dependent Surveillance (ADS), multi-lateration, communication).” From an aircraft and operational perspective, RNAV equipment provides the ability to automatically determine aircraft position from one or more of a variety of navigation information sources. RNAV equipment typically includes one or more of the following components: GNSS, INS, DME-DME.

RNP and GNSS initiatives are directly interrelated in that GNSS facilitates RNP. Without GNSS, operational RNP will be more difficult to implement on a global basis. However, GNSS does not guarantee the success of RNP.

The third modernization initiative depends in large measure on the joint success of the RNP and GNSS initiatives together leading to a robust, seamless, and pervasive RNP-compliant RNAV capability. This RNP RNAV capability, combined with communications and surveillance initiatives, will then lead to a CNS/ATM environment that can support "Free Flight" operations.

Free Flight is "a safe and efficient flight operating capability under Instrument Flight Rules (IFR)" in which the operators have the freedom to select their path and speed in real-time. Air traffic restrictions are only imposed to ensure separation, to preclude exceeding airport capacity, to prevent unauthorized flight through Special Use Airspace (SUA), and to ensure safety of flight. Restrictions are limited in the extent and duration to correct the unidentified problem. Any activity which removes restrictions represents a move toward free flight."

The building-block nature of the ICAO initiatives ultimately leading to Free Flight is shown in Figure 1.

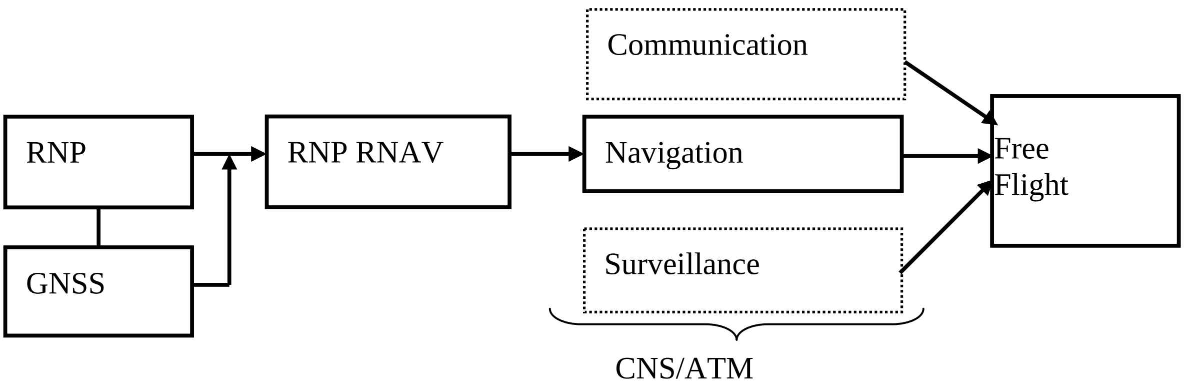

Figure 1. Building Blocks Leading to Free Flight and CNS/ATM.

301 Required Navigation Performance (RNP)

ICAO Doc 9613, RTCA/DO-236 and ED-75 RNP initiatives include but are not limited to:

- Distilling the fundamental performance characteristics of existing ground-based aeronautical radionavigation systems,
- Analyzing those performance characteristics to determine their contribution to the safety and efficiency of today's flight operations,
- Defining the minimum required navigation performance characteristics to support safe and efficient flight for the foreseeable future,
- Modernizing international civil aviation to satisfy those defined minimum required navigation performance characteristics, and
- Discussing containment as the key to performance.

RNP is an RNAV operation, with the fundamental addition of on-board navigation performance monitoring and alerting to the pilot whether or not the operational requirement is met. This on-board performance monitoring and alerting capability can reduce reliance on increased route separation and/or air traffic control interventions to maintain the overall safety of the operation.

Air navigation requirements have customarily been specified in terms of carriage requirements (i.e. the air navigation equipment the aircraft must carry). The carriage requirements for IFR flight for a given route or procedure can be as simple as a single VOR or as complex as triple inertial navigation systems with redundant DMEs and autopilots.

National CAAs are responsible for the routes or procedures that ensure that adequate ground-based radionavigation transmitters or transceivers are installed and operating so that a route or procedure can be flown by aircraft meeting the carriage requirement.

The RNP initiative acknowledges that many different configurations of air navigation equipment are capable of providing sufficient performance to safely fly a given route or procedure. By specifying the minimum required navigation performance characteristics for various routes and procedures, RNP enables different configurations of air navigation equipment to be used for a route or procedures, provided that the particular configuration of air navigation equipment satisfies the minimum required navigation performance characteristics for the routes or procedures. Focusing on minimum required navigation performance characteristics rather than on specific equipment carriage requirements has led many to describe RNP as being “sensor independent.”

Much has already been accomplished on the RNP initiative. A top-level guide to the implementation of RNP is given in the ICAO Manual on Required Navigation Performance (RNP) (Doc. 9613-AN/937). In certain airspace, compliance with RNP has already been mandated. For example, much of the airspace over the Pacific Ocean and all high altitude routes over Europe currently specify RNP compliance. RNP is supported by the commercial aviation industry as evidenced by avionics systems like the "Future Air Navigation System" (FANS) installed on many Boeing and Airbus aircraft.

The basic RNP characteristic is navigation accuracy relative to a desired path, where the path is defined either in terms of the location of ground-based radionavigation transmitters/transceivers or a series of geographically referenced waypoints.

For RNP, navigation accuracy applies to the actual achieved guidance of the aircraft relative to the desired path. It therefore encompasses the Total System Error (TSE); including the Flight Technical Error (FTE) due to piloting as well as the Navigation System Error (NSE), Path Definition Error (PDE), and Display System Error (DSE).

$$TSE = FTE + NSE + PDE + DSE$$

The RNP definition of navigation accuracy does not specify the trade-offs between these various sources of error.

The RNP initiative does not directly address any of the secondary factors commonly associated with navigation performance, namely: navigation accuracy, integrity, continuity, and availability. This is entirely appropriate considering the top-level focus of RNP on TSE under fault-free conditions. Because the RNP initiative does not specify the trade-offs between FTE, NSE, PDE, and DSE, it would be inappropriate for the RNP initiative to try to specify characteristics like integrity, continuity, and availability which are usually applied only to the NSE. Furthermore, the RNP initiative properly keeps its focus on fault-free conditions which are known to prevail nearly all the time. Integrity, continuity, and availability relate to fault conditions which are relatively rare. These secondary factors are acknowledged (e.g., pilot blunders as an FTE fault), but they are not directly addressed by the RNP initiative.

302 Global Navigation Satellite System (GNSS)

ICAO Annex 10 was used from the 1940s through the 1980s to standardize and formally adopt the various ground-based radionavigation systems for international civil aviation use. The same process was used again in the 1990s and early 2000s to standardize and formally adopt today's satellite-based radionavigation signals. Aviation authorities and other participants, such as manufacturer representatives, formed a GNSS Panel (GNSSP)* comprised of experts from many nations to work through the myriad of technical and operational details. Successful harmonization of stakeholder needs resulted in the bulk of Amendment No. 76 to Annex 10, often referred to as the "GNSS SARPs.". Amendment No. 76 also includes small changes to some of the ground-based radionavigation signals. The Council of ICAO adopted Amendment No. 76 on 12 March 2001 with an applicable date of 1 November 2001.

*NOTE: the GNSSP has recently been renamed as the Navigation Systems Panel (NSP).

The GNSS SARPs address satellite-based radionavigation signals from systems that are currently used by international civil aviation, namely the civil services of US GPS and the Russian Global Navigation Satellite System (GLONASS). It also addresses aircraft-based augmentation systems (ABASs) that exploit additional information available in the aircraft -- either from GNSS receivers which track and use more than the minimum number of GNSS signals (as in the case of Receiver Autonomous Integrity Monitoring [RAIM]), or from additional navigation or timing systems (as in the case of Aircraft Autonomous Integrity Monitoring [AAIM]) -- to augment the basic GNSS performance. The GNSS SARPs further address augmentation signals from external systems that are expected to enter into use by international civil aviation in the near future.

In preparing the GNSS SARPs, the GNSSP working groups were able to rely on several sources for detailed specifications on the radionavigation system signal characteristics and the augmentation system signal characteristics. Of particular note for the GPS SPS signal characteristics, the material contained in the GNSS SARPs came almost exclusively from the Global Positioning System (GPS) Standard Positioning Service (SPS) Signal Specification, 2nd Edition, published and promulgated by the US DoD on 2 June 1995. This document has been superseded by the Global Positioning System

Standard Positioning Service Performance Standard, 4 October 2001 and Navstar GPS Space Segment/Navigation User Interfaces, IS-GPS-200D, 7 December 2004. Likewise, the SBAS and GBAS material contained in the GNSS SARPs came almost exclusively from RTCA and EUROCAE documents.

One area where the GNSSP working groups had to do substantial new work was in the definition of the NSE requirements for the GNSS. For consistency with the RNP initiative, these NSE requirements had to be consistent with the required navigation accuracy as defined for the various RNP types (levels). However, unlike the RNP initiative, the GNSS SARPs NSE requirements had to go to additional lengths to specify the required NSE integrity, required NSE continuity, and required NSE availability of the GNSS Signals in Space (SIS) for standardization purposes.

The required SIS NSE accuracy forms the basis for the other three required SIS NSE parameters because it establishes the usability threshold for GNSS SIS -- a navigation system's SIS must either be able to satisfy the SIS NSE accuracy or else it is not useable for the RNP type. The SIS NSE integrity is the parameter most closely identified with safety since integrity demands a timely warning be issued when the system is not safe to be used. SIS NSE continuity is the cross-over parameter between safety and efficiency since an unexpected loss of navigation guidance will adversely impact safety unless a redundant back-up capability is available (redundant back-ups increase cost). SIS NSE availability is the efficiency parameter because non-availability limits where and/or when the system can be used. In summary:

Signal In Space (SIS) Navigation System Error (NSE) Parameter	**Effect/Impact on Aviation Operations**
Accuracy	Usability
Integrity	Safety
Continuity	Safety/Efficiency
Availability	Efficiency

The SIS NSE requirements from the GNSS SARPs portion of ICAO Annex 10, including the associated explanatory notes, are repeated below in Table 1 for reference.

For the associated RNP types specified by two numbers, the first RNP number is the required horizontal TSE in nm at the 95th percentile probability and the second RNP number is the required vertical TSE in ft at the 95th percentile probability.

Table 1. SIS NSE Requirements from ICAO (GNSS) SARPs ANNEX 10, Table 3.7.2.4-1, Amendment 80, 24 November 2005.

Typical Operation(s)	Accuracy - Horizontal 95% (1)(3)	Accuracy - Vertical 95% (1)(3)	Integrity (2)	Time to alert (3)	Continuity (4)	Availability (5)
En Route	3.7 km (2.0 nm) **(6)**	N/A	$1\text{-}10^{-7}$/h	5 min	$1\text{-}10^{-4}$/h to $1\text{-}10^{-8}$/h	0.99 to 0.99999
En Route, Terminal	0.74 km (0.4 nm)	N/A	$1\text{-}10^{-7}$/h	15 s	$1\text{-}10^{-4}$/h to $1\text{-}10^{-8}$/h	0.99 to 0.99999
Initial Approach, Intermediate Approach, Non-Precision Approach (NPA), Departure	220 m (720 ft)	N/A	$1\text{-}10^{-7}$/h	10 s	$1\text{-}10^{-4}$/h to $1\text{-}10^{-8}$/h	0.99 to 0.99999
Approach with Vertical Guidance (APV-I)	16 m (52 ft)	20 m (66 ft)	$1\text{-}2\times10^{-7}$ per approach	10 s	$1\text{-}8\times10^{-6}$ in any 15 s	0.99 to 0.99999
Approach with Vertical Guidance (APV-II)	16.0 m (52 ft)	8.0 m (26 ft)	$1\text{-}2\times10^{-7}$ per approach	6 s	$1\text{-}8\times10^{-6}$ in any 15 s	0.99 to 0.99999
Category I Precision Approach (8)	16.0 m (52 ft)	6.0 m to 4.0 m **(7)** (20 ft to 13 ft)	$1\text{-}2\times10^{-7}$ per approach	6 s	$1\text{-}8\times10^{-6}$ in any 15 s	0.99 to 0.99999

1. The 95 percentile values for GNSS position errors are those required for the intended operation at the lowest height above threshold (HAT), if applicable.

2. The definition of the integrity requirement includes an alert limit against which the requirement can be assessed. These alert limits are:

Typical Operation(s)	Horizontal Alert Limit	Vertical Alert Limit
En-route (oceanic/continental low density)	7.4 km (4 NM)	N/A
En-route (continental)	3.7 km (2 NM)	N/A
En-route, Terminal	1.85 km (1 NM)	N/A
NPA	556 m (0.3 NM)	N/A
APV-I **(9)**	556 m (0.3 NM)	50 m (164 ft)
APV-II **(9)**	40.0 m (130 ft)	20.0 m (66 ft)
Category I Precision Approach	40.0 m (130 ft)	15.0 m to 10.0 m (50 ft to 33 ft)

A range of vertical limits for Category I precision approach relates to the range of vertical accuracy requirements.

3. The accuracy and time-to-alert requirements include the nominal performance of a fault-free avionics receiver.

4. Ranges of values are given for the continuity requirement for en-route, terminal, initial approach, NPA and departure operations, as this requirement is dependent upon several factors including the intended operation, traffic density, complexity of airspace and availability of alternative navigation aids. The lower value given is the minimum requirement for areas with low traffic density and airspace complexity. The higher value given is appropriate for areas with high traffic density and airspace complexity.

5. A range of values is given for the availability requirements as these requirements are dependent upon the operational need which is based upon several factors including the frequency of operations, weather environments, the size and duration of the outages, availability of alternate navigation systems, radar coverage, traffic density and reversionary operational procedures. The lower values given are the minimum availabilities for which a system is considered to be practical but are not adequate to replace non-GNSS navigation systems. For en-route navigation, the higher values given are adequate for GNSS to be the only navigation aid provided in an area. For approach and departure, the higher values given are based upon the availability requirements at airports with a large amount of traffic assuming that operations to or from multiple runways are affected but reversionary operational procedures ensure the safety of the operation.

6. This requirement is more stringent than the accuracy needed for the associated RNP types, but it is well within the accuracy performance achievable by GNSS.

7. A range of values is specified for Category I precision approach. The 4.0 m (13 ft) requirement is based upon ILS specifications and represents a conservative derivation from these specifications.

8. GNSS performance requirements for Category II and III precision approach operations are under review and will be included at a later date.

9. The terms APV-I and APV-II refer to two levels of GNSS approach and landing operations with vertical guidance (APV) and these terms are not necessarily intended to be used operationally.

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CHAPTER 4. CURRENT STATUS OF GPS SPS/PPS USE IN CIVIL AIRSPACE

401 Civilian Use

401.1 *Reference Documents*

Civil GNSS avionics standards are imposed by each CAA as part of the airworthiness certification process.

US and Europe are the two major contributors of standardization documents for user equipment.

The European national CAAs originally collaborated under the Joint Aviation Authority (JAA). They have since regrouped under the European Aviation Safety Authority (EASA) to generate and impose common regulatory documents. The EURopean Organisation of Civil Aviation Equipment manufacturers (EUROCAE) produce industry standards.

In the US the Federal Aviation Administration (FAA) prepares and imposes the regulatory documents while RTCA (formerly known as Radio Technical Commission for Aeronautics) generates industry standards.

- Regulatory Documents:
    - EU: EASA
    - USA: FAA
- Industry Standards:
    - EU: EUROCAE
    - USA: RTCA

Most of the US and European regulatory documents and standards are equivalent. The following table provides details about the equivalence (or differences) between the most relevant US and European documents and standards. The EASA/FAA and EUROCAE/RTCA documents and standards are used throughout the world.

Industry Standards			
OBJECT	USA (RTCA)	EUROPE (EUROCAE)	COMMENTS
Concept RNP RNAV	DO-236()	ED-75()	Strict equivalence
Airborne Supplemental Navigation Equipment using GPS	DO-208()	ED-72()	Partial Equivalence. ED 72 A does not cover VNAV. The strict equivalence is given by the following combination ED-72A =DO-208+TSO-C129a
Airborne Navigation Sensor using GPS/WAAS	DO-229()	-	No equivalence in Europe. The CS-ETSO C145 calls the US document for GPS/WAAS
Multi sensor Equipments using GPS for RNAV	DO-187()	ED-58()	Strict equivalence
Processing of Aeronautic information	DO-200()	ED-76()	Strict equivalence
Aeronautic Information	DO-201()	ED-77()	Strict equivalence
Software development guidelines	DO-178()	ED-12B()	Strict equivalence
Airborne and Ground Equipment LAAS/GBAS	DO-245()	ED 95()	Compatible– ED 95 considers only CAT I approach.
Airborne receiver GPS/LAAS (GBAS)	DO-253()	-	-

RNP-RNAV REGULATORY DOCUMENTS			
OBJECT	USA (FAA)	EUROPE (EASA / JAA)	COMMENTS
P-RNAV	AC 90-96A	TGL 10	P-RNAV is a temporary method chosen by Europeans to implement RNP-1 RNAV
RNP	ICAO Doc 7030 (9613- AN/937) RNP Manual		

REGULATORY DOCUMENTS			
OBJECT	USA (FAA)	EUROPE (EASA / JAA)	COMMENTS
Multi sensor system using GPS	TSO C115()	CS-ETSO C115()	Equivalence
Supplemental navigation equipment using GPS	TSO C129()	CS-ETSO C129()	Equivalence
Navigation Sensors using WAAS	TSO C145()	CS-ETSO C145()	Equivalence
Autonomous Navigation Equipment using GPS/WAAS	TSO C146()	CS-ETSO C146()	Equivalence

TECHNICAL GUIDES			
Object	USA (FAA)	EUROPE (EASA / JAA)	Comments
RNAV systems for use in NAS	AC 90-45 A AC 90-100	AMC 20-5	Global Equivalence since AMC 20-5 uses AC 20-130A and 20-138 as certification basis for GPS installations
Functionality and Performances for multi sensors navigation Equipments	AC 20-130 A		
Stand-Alone GPS	AC 20-138 AC 20-138a		
IFR GPS Operations for En Route, Terminal and NPA phases in NAS	AC 90-94 A	AMC 20-5 and TGL3	Quasi equivalence put aside Organization and structure differences
RNP RNAV Approach	-	TGL XY	TGL XY is not yet published.
NPA /RNAV using GPS	-	TGL XZ	TGL XZ is not yet published.

Class of GPS IFR Equipment (TSO C129a or CS-ETSO C129a)						
Class of Equipment	**RAIM**	**Integrated NAV system providing Integrity monitoring**	**Oceanic Capability**	**En Route Capability**	**Terminal Capability**	**NPA Capability**
CLASS A – GPS Sensor and Navigation Module						
A1	Yes		Yes	Yes	Yes	Yes
A2	Yes		Yes	Yes	Yes	No
CLASS B – GPS sensor providing data to an integrated navigation system (FMS, Multi sensor NAV System etc.)						
B1	Yes		Yes	Yes	Yes	Yes
B2	Yes		Yes	Yes	Yes	No

B3		Yes	Yes	Yes	Yes	Yes
B4		Yes	Yes	Yes	Yes	No
Class C – GPS sensor providing data to an integrated navigation system (FMS, Multi sensor NAV System etc.) and providing a guidance enhancement information for automatic pilot or flight director to reduce the TFE						
C1	Yes		Yes	Yes	Yes	Yes
C2	Yes		Yes	Yes	Yes	No
C3		Yes	Yes	Yes	Yes	Yes
C4		Yes	Yes	Yes	Yes	No

401.2 *Summary on Authorized use of GPS for IFR flights*

The following table provides the operational capabilities of TSO-C129 or CS-TSO-C129 compliant GPS receivers:

In the 42 countries composing the European Civil Aviation Conference (ECAC), an international organization harmonizing civil aviation policies and practices between its member states, stipulates GPS SPS can be used in the following conditions (All European NATO nations are in the ECAC):

- En-Route: The requirement for the carriage of on-board Basic RNAV (B-RNAV) equipment was mandated from April 1998 in en-route airspace of the ECAC States. The use of GPS to perform Basic RNAV operations is limited to equipment approved to TSO-C129() IAW TGL No. 2 (rev.1).

- Terminal: Precision RNAV (P-RNAV) is intended for terminal operation. The use of GPS to perform P-RNAV operations is limited to equipment approved under FAA TSO-C145() and TSO-C146(), and JTSO-C129()/TSO-C129() (class A1, B1, C1, B3 or C3) IAW TGL No.10. Some states also allow the equipment to be approved under TGL No.3 and TGL No.3 (rev.1) for GPS procedures in RNAV Terminal operations until 2010 (at the latest).

In Canada, GPS SPS can be used in the following conditions:

- En-Route and Terminal: GPS may be used for all en-route and terminal operations, including navigation along airways and air routes, navigation to and from ground-based aids along specific tracks, and area navigation (RNAV). The use of GPS is limited to equipment approved to TSO-C129() (any class), TSO-C145(), TSO-C146() or equivalent.

- Approach: GPS can be used to fly GPS stand-alone and GPS overlay approaches. The use of GPS is limited to equipment approved to TSO-C129() (Class A1, B1, B3, C1 or C3), TSO-C145(), TSO-C146()or equivalent.

In United States, GPS SPS can be used in the following conditions:

- En-Route (Oceanic/Remote) and Terminal: GPS may be used as a supplemental means of navigation if equipment is approved to TSO-C129() (any class), or as a primary means of navigation if equipment is approved to TSO-C145()/TSO-C146().

- Non Precision Approach: GPS may be used as a supplemental means of navigation if equipment is approved to TSO-C129() (Class A1, B1, B3, C1 or C3), or as a primary means of navigation if equipment is approved to TSO-C145()/TSO-C146().

APPENDIX A contains a list of the countries authorizing the use of GPS in their national airspace. It is important to note that the usage of GPS may vary between States.

402 Military Use

402.1 *GPS PPS for En Route, Terminal, and Non-Precision Approach Operations*

Most military aircraft have installed at least one GPS antenna and one GPS receiver. On military aircraft, the GPS antennas provide reception of the PPS signals for both the L1 band (1563.42 - 1587.42 MHz) and the L2 band (1215.6 - 1239.6 MHz). The GPS receivers process the PPS signals from both frequencies to generate highly accurate navigation solutions. Some types of GPS PPS receivers are designed to operate as a separate line replaceable unit (LRU) in a stand-alone configuration with its own display unit. Other types of GPS PPS receivers are separate LRUs designed to operate in conjunction with a suite of other navigation systems in a multi-sensor configuration. Still other types of GPS PPS receivers are no more than cards or modules designed to be embedded in, and work tightly coupled with, another LRU like an inertial navigation system (INS) or a Doppler navigator.

Most GPS PPS receivers on military aircraft are used primarily as sources of position. The actual navigation functions are determining the desired path from stored waypoint data, computing deviations relative to that path, and displaying the resulting guidance information to the pilot or outputting it to an autopilot. These functions are performed outside the PPS receiver. The PPS receiver in these cases is thus called a position sensor (or "navigation sensor").

Regardless of whether a PPS receiver is used only as a navigation sensor or as the actual navigation system, its accuracy is generally far better than the RNP accuracy required by ICAO Doc. 9613-AN/937, or the RNAV accuracy required by FAA AC 90-45A, or the RNP RNAV accuracy required by RTCA DO-236(), for all phases of flight other than precision approach. In those infrequent instances where the accuracy of a PPS receiver is significantly degraded due to encountering bad geometric conditions, some PPS receivers provide a near-instantaneous warning of that degradation for display to the pilot or for output to the autopilot. PPS receivers may also include a RAIM algorithm for detecting SIS anomalies.

402.2 *GPS PPS for Precision Approach Operations*

In parallel with ICAO's interest in considering local area differential GPS (LADGPS) techniques for precision approach operations using GBAS (LAAS in the US), military aviation is also considering the use of LADGPS techniques for precision approach operations using a GBAS-like system (e.g. the Joint Precision Approach and Landing System [JPALS] in the US).

The primary difference between the civil and military aviation use of LADGPS techniques is that the civil GBAS system will be limited to only using the SPS signal in the L1 band while the military GBAS-like system will be capable of using the PPS signals in both the L1 and L2 bands as well as the SPS signal in the L1 band. The only purpose of the military GBAS-like system using the SPS signal in the L1 band is to provide military-civil interoperability: it will allow civil aircraft with a GBAS capability to land at military airfields with a GBAS-like ground system in an emergency and allow military aircraft with an GBAS-like capability to land at civil airfields with a GBAS capability during routine peacetime operations.

The potential military use of LADGPS techniques for precision approach operations using a GBAS-like system is currently being addressed within NATO. The Approach and Landing Systems Joint Working Group (ALS JWG) has been established through collaboration between NATO Air Force Armaments Group (NAFAG) Aerospace Capability Group 5 (ACG/5) and NC3B SC/8. Three Standardization Agreements (STANAGs) have been created and address the technical and operational details associated with military use of LADGPS techniques. The most intimately related of these is STANAG 4550, Use of Differential Global Positioning System (DGPS) For Military Precision Approach and Landing and STANAG 4533, Precision Approach and Landing System Transition Strategy both under the sponsorship of NAFAG (ACG/5). The other is Annex D of STANAG 4392, "Format and Usage Of PPS DGPS Messages For Aviation And Other High-Performance Applications" under the sponsorship of NC3B SC/8.

402.3 *Current Military Flight Operations in Civil Controlled Airspace*

Currently TACAN and ILS are the major radionavigation sources for IFR flight of military aircraft in civil controlled airspace. Military aircraft that frequently operate in civil controlled airspace commonly use VOR/DME where TACAN is unavailable. There has been a significant increase in the number of inertial navigation systems being used, particularly in integrated multisensor systems.

When GPS is used for supplemental means IFR navigation in civil controlled airspace, it is typically done using an SPS receiver, which has been certified to civil standards or a PPS receiver which has been approved by national authorities. Table 2 identifies some nations which have expressed a policy in regards to GPS PPS usage for en-route through non-precision approaches.

Table 2: Nations having expressed a policy in regards to GPS PPS Usage for En Route through Non-Precision Approach in civil controlled airspace

NATIONS	**POLICY**
Canada	GPS PPS may be used as if it is GPS SPS.
Czech Republic	The Czech civil controlled airspace designated for Basic RNAV does not allow anything but supplemental means of GPS approved to TSO C-129 together with additional Navigational aids (for backup) in accordance to the directive of CAA AIC A 14/97. This directive is fully in line with the approved TGL No.2 rev.1-AMJ 20X2.
France	Military aircraft equipped with GPS PPS can be accepted in civilian airspace if the military Authority certifies they are able to respect the civilian requirements. In practice the PPS is used as secondary mean of navigation with other equipments (VOR/DME for example)
Germany	Helicopters stand-alone GPS PPS Trimble CUGR allowed for terminal, NPA, and En Route if valid ED-76 or DO-200A compliant data cards are loaded. If not, only En Route and B-RNAV are allowed. GPS PPS can be used, in most cases, with limitations/restrictions or specific pilot procedures. For flights under IFR, it is mandatory that a second ground base navigation system (e.g. TACAN) is operational.
Italy	GPS PPS allowed during En Route and B-RNAV phases only, provided that a "loose coupling" configuration is used as hybridization solution at the platform level between GPS and Inertial sensors.
Netherlands	Neither GPS SPS nor GPS PPS have been certified for use within Amsterdam FIR. The certification process for the use of GPS SPS is presently underway within the EASA (European Aviation Safety Agency). Until the EASA has certified GPS, GPS is not allowed to be used in Amsterdam FIR as the primary means of navigation. GPS is allowed to be used as secondary means.
Spain	GPS PPS may be used as if it is GPS SPS. The MoD - Spanish Air Force and the Spanish Civil Aviation Authority (Ministry of Public Works - General Directorate of Civil Aviation, DGAC) coordinate air navigation rules and issues throughout a long established Joint Committee at Ministry level.
United Kingdom	UK airspace does not allow anything but supplemental means SPS GPS approved to TSO C-129 and still requires carriage of approved aids IAW UK Navigation Order in Controlled Airspace unless exempted.
United States	GPS PPS may be used. DoD has authority to self-certify their aircraft for operations in civil airspace. (ex. MH-53 at the platform level and TA-12 at the equipment level).

402.3.1 Current Military Flight Operations Outside Civil Controlled Airspace.

Outside of civil controlled airspace, military aircraft currently conduct flight operations as dictated by the mission. Navigation by visual means is common, particularly for helicopters which often do not have avionics that would allow instrument flight. Where available, TACAN and ILS continue to be major radionavigation sources for IFR flight. Self-contained systems (INSs or Doppler navigators) are typically used in areas where ground-based radionavigation signals are unavailable. PPS receivers operating in the PPS mode are used as needed, either as a primary source of navigation guidance or as a primary source of data for updating an INS or Doppler navigator. In many areas of the world, GPS is the only radionavigation aid available for military aviation.

CHAPTER 5. GPS SIGNAL IN SPACE (SIS)

The characteristics of the SIS determine the basic performance of GPS. While there may be many different types of airborne receiving equipment, the performance capabilities of each type of equipment are constrained by the SIS. The airborne equipment cannot do any better than what the SIS will allow.

501 GPS SIS Documentation

There are three types of GPS SIS documents relevant to authorization of the GPS SIS. The three types are: Interface Control Documents (ICDs) or Interface Specification (IS) documents, Performance Standards (PSs), and NATO Standardization Agreements (STANAGs). Each type of document has a specific purpose. The purpose of each type of document is as follows:

ICDs/ISs The GPS SIS ICDs and ISs (e.g., 200, 222, 224, 225, & 227) define the technical requirements related to the SIS interface from the Navstar GPS satellites to the GPS user equipment (UE). The requirements defined in each ICD or IS are focused primarily on the radio frequency (RF) characteristics of the transmitted SIS, the coarse acquisition (C/A) and precision (P(Y)) code pseudorandom noise (PRN) sequences, and the content, format, and utilization protocols of the navigation (NAV) data message.

PSs The GPS SIS PSs (i.e., SPS PS & PPS PS) define the performance requirements related to the SIS broadcast from the Navstar GPS satellites to the GPS UE. The operational performance requirements defined in each PS are focused primarily on the coverage, accuracy, integrity, continuity, and availability of the broadcast SIS.

STANAGs The GPS SIS STANAG (i.e., STANAG 4294) defines the system characteristics related to the SIS interface from the Navstar GPS satellites to the GPS UE that are essential to the design of NATO GPS UE.

502 GPS SIS Baselines

The GPS SIS ICDs/ISs and the GPS SIS PSs are the baselines for the GPS SIS provided by the United States Government. Barring intentional or unintentional disruption of the GPS SIS, the United States Government is committed to operate the SIS as specified in the GPS SIS Baselines. Intentional termination or modification of the GPS SIS will be announced-well-in-advance.

In the above context, it is understood that “announced-well-in-advance” means an announcement at least 6 years prior to any permanent termination or interface modification. For operational disruptions of a temporary nature (e.g., the outage of the SIS from a single satellite), “announced-well-in-advance” is taken to mean an announcement at least 48 hours prior to the disruption.

503 GPS SIS Commissioning

503.1 *GPS SIS Commissioning for the SPS*

503.1.1 Initial Commissioning Baseline for the SPS SIS

The GPS SPS SIS was initially commissioned with the publication of the *Global Positioning System (GPS) Standard Positioning Service (SPS) Signal Specification* on 5 November 1993. The letter promulgating this baseline was signed by the US DoD Office of the Assistant Secretary of Defense on 8 December 1993. The promulgation was part of the declaration of Initial Operating Capability (IOC) for GPS.

This *GPS SPS Signal Specification* was a combination of the SPS portions of the unclassified ICD for the GPS SIS (i.e., *Navstar GPS Space Segment / Navigation User Interfaces*, ICD-GPS-200) and the relevant unclassified SPS portions of the GPS performance requirement specifications (multiple sources). The *GPS SPS Signal Specification* took this form because of the following two limitations:

a. The *GPS SPS Signal Specification* could not simply reference ICD-GPS-200 for the SPS SIS technical interface requirements because ICD-GPS-200 had not yet been approved for public release. In 1993, ICD-GPS-200 was still restricted as For Official Use Only (FOUO).
b. The *GPS SPS Signal Specification* could not simply reference the source documents for the SPS SIS operational performance requirements because the source documents were restricted as being either classified or FOUO. In 1993, selective availability (SA) was being used to operationally degrade the SPS SIS performance.

The *GPS SPS Signal Specification* overcame these two limitations by extracting the essential SPS SIS information from ICD-GPS-200 and the GPS performance requirement specifications, and then recasting that information into a publicly releasable form.

503.1.2 Second Commissioning Baseline for the SPS SIS

The second edition of the *GPS SPS Signal Specification* was baselined and promulgated to the public on 2 June 1995. This Second Edition was an update to the original *GPS SPS Signal Specification* which clarified some of the technical interface details and added a few additional operational performance requirements for the SPS SIS. The added operational performance requirements addressed the SPS SIS range domain signal dynamics and served primarily as operational bounds on the use of SA for degrading SPS performance.

503.1.3 Third Commissioning Baseline for the SPS SIS

The third edition of the *GPS SPS Signal Specification* was significantly de-scoped when ICD-GPS-200 was released to the public on 25 September 1997. With ICD-GPS-200 no longer FOUO, the *GPS SPS Signal Specification* could be substantially reduced in size by simply referring to ICD-GPS-200 as the

SPS SIS technical interface requirements baseline for certification. Although this did not actually reduce the scope of the certification baseline since the total number of SPS SIS requirements remained the same, it did eliminate the duplication of technical interface requirements between ICD-GPS-200 and the *GPS SPS Signal Specification*.

The scope of the third edition of the *GPS SPS Signal Specification* was further modified as a result of the decision to discontinue the use of SA for degrading the SPS performance effective 1 May 2000. The discontinuance of SA shifted the focus towards expressing the SPS SIS operational performance requirements directly in their native form rather than indirectly expressing them through their composite net effect on the navigation of a hypothetical end user with a particular type of SPS receiver (i.e., an SPS receiver which only tracks satellites above a mask angle of 5 degrees and which only processes a maximum of 4 satellites simultaneously). For the first time, the baseline 24-slot satellite constellation could be publicly specified in a manner independent of any airborne SPS receiver mask angle limitations or processing assumptions. Also for the first time, the SPS SIS range domain performance requirements could be specified in public rather having to be inferred from range domain signal dynamic bounds.

To mark the paradigm shifts brought about by the discontinuance of SA and the ability to reference a publicly released ICD-GPS-200, the third edition of the *GPS SPS Signal Specification* was scrapped. In its place, a new certification document for the SPS SIS was created and named the *GPS SPS Performance Standard*. The *GPS SPS Performance Standard* ("*SPS PS*" for short) was baselined and released to the public on 4 October 2001.

503.2 *GPS SIS Commissioning for the PPS*

503.2.1 Initial Commissioning Baseline for the PPS SIS

The commissioning of the PPS portion of the GPS SIS is following the paradigm established with the SPS PS using simple references to ICD-GPS-200, ICD-GPS-222, ICD-GPS-224, ICD-GPS-225, and ICD-GPS-227 as the sources of the PPS SIS technical interface requirements baseline for commissioning. This document, known as the PPS Performance Standard (PPS PS), defines the levels of performance the U.S. Government makes available to authorized users of the GPS Precise Positioning Service (PPS).

504 Verification/Validation for GPS SIS Baselines

There are two verification/validation processes under the authority of the US Air Force directly supporting the GPS SIS baselines (original and continuing). There is also at least one independently recognized entity, the Federal Aviation Administration (FAA), confirming one of the GPS SIS baselines.

504.1 *Original Verification/Validation for GPS SIS Baseline*

The original verification/validation process, under the GPS JPO authority, confirmed that the GPS SIS satisfied the commissioning baseline requirements and that there was an assured margin of confidence indicating the GPS SIS would continue to satisfy the baseline requirements. Conformance with each GPS SIS baseline, whether new or modified, is verified/validated using the analysis, demonstration, inspection, and test data collected throughout the development and deployment of the system. The GPS SIS baselines always trace – whether directly or indirectly – to the existing system/segment/interface requirements.

The data for the original verification/validation process comes from a multitude of tests: verification tests, qualification tests (including interface compatibility tests), acceptance tests, and operational tests (including both developmental test and evaluation [DT&E] and operational test and evaluation [OT&E]).

504.2 *Continuing Verification/Validation for GPS SIS Baseline Requirements*

The purpose of the continuing verification/validation process is to confirm on an on-going basis that the GPS SIS continues to satisfy the baseline requirements.

The continuing verification process comprises a regimen of monitoring, analyzing, and confirming GPS SIS satisfaction of the baseline requirements. For both the PPS SIS and SPS SIS, the Control Segment (CS) performs most of the routine monitoring and analyzing as part of normal operations. Additional special monitoring and analysis efforts are outsourced to external organizations with the requisite facilities and capabilities. One example of this type of special monitoring and analysis is the use of a high-gain parabolic dish antenna to verify the transmitted PPS and SPS signal power from each satellite.

504.3 *Independent / Third Party Confirmation of GPS SIS Baseline Requirements*

The nature of the GPS SIS allows users to independently confirm that GPS SIS satisfies the baseline requirements. As a particularly important example, the FAA independently monitors the SPS SIS performance and analyzes its characteristics to confirm that it satisfies its GPS SIS baseline requirements within the U.S. National Airspace System (NAS). The FAA publishes the results of the efforts in quarterly performance analysis reports. These reports are made available to the public on the web at http://www.nstb.tc.faa.gov/. The FAA has been producing their quarterly performance analysis reports continually since 1993 (the same year the *GPS SPS Signal Specification* was released).

505 Operational Approval

Neither the GPS SIS nor any of its individual portions are designed to support a specific application.

There is no guarantee, either expressed or implied, that the PPS SIS or SPS SIS are necessarily suitable or appropriate for any specific end-user application. The responsibility for deciding to use or not use a portion of the GPS SIS for any end user application rests solely with the end user.

Many end user applications are regulated by either a governmental or quasi-governmental organization. For example, civil aviation use of GPS is an application regulated by both governmental organizations (e.g., the cognizant civil aviation authority for each region of sovereign airspace around the globe) and by a quasi-governmental organization (i.e. ICAO). Where such regulation exists, it is usually up to the regulator to approve the PPS and/or SPS portions of the GPS SIS for operational use in each specific application.

In the U.S. NAS, the FAA has approved the use of the GPS SPS SIS for civil airspace. Some civil airspace operations are subject to restrictions and limitations including, but not limited to, user equipment. A brief chronology summarizing some of the FAA approvals of the GPS SIS for specific civil aviation applications is given below.

Feb 1991	GPS approved as an input to multisensor navigation systems
Jun 1993	GPS approved for supplemental use for en route through non-precision approach (NPA)
Feb 1994	FAA Administrator announced GPS to be operational and an integral part of the U.S. air traffic control system
Jun 1994	First GPS helicopter approach approved
Dec 1994	GPS approved as primary means of navigation in oceanic and remote airspace
Feb 1998	GPS approved for use in Required Navigation Performance (RNP) -10 airspace
Mar 1998	GPS approved for use in basic area navigation (BRNAV) / RNP-5 airspace
Jul 1998	GPS approved for use in lieu of automatic direction finder (ADF) and distance measuring equipment (DME) in en route and terminal operations

The following table represents recent certification of military UE and platforms in the US. These are examples of approval of the PPS portion of the GPS SIS for operational use in the US NAS.

Jan 2004	Approval for Fleet Introduction of the Miniaturized Airborne Global Positioning System (GPS) Receiver (MAGR 2000) Equipped MH-53R
Sep 2004	MSO-C129a Authorization granted by GPS JPO to Trimble for the Tasman ARINC-12 GPS Receiver (TA-12)

CHAPTER 6. CIVIL AND MILITARY USER EQUIPMENT CERTIFICATION PROCESS

601 Civil Certification

The Chicago Convention of 1949 gives the international principles for the certification of aircraft and personnel licensing, mainly in chapters V and VI. Those chapters are complemented by Annex 8 which details with the procedures and airworthiness codes.

Although ICAO cannot mandate standards for equipment function, the standards and recommended practices (SARPs) developed by ICAO, are recognized as technical obligations.

From the ICAO point of view, an Airworthiness certificate is mandatory for international flights. For domestic flights each country can apply its own rules, but they are often identical to the ICAO SARPs.

Regarding the international acceptance of an airworthiness certificate, article 33 of the Chicago Convention poses the principle that if an aircraft has been certified by the competent services in one country, given signatory to the convention, and applying the ICAO recommendation for airworthiness standards and procedures, the other ICAO countries should recognize this certification.

However, the airworthiness standards in Annex 8 of the Chicago Convention lack explicit detail and cannot be used directly as a unique standard for all countries. It is for this reason that some countries (or group of countries) have developed their own airworthiness standards. For example, the USA the European nations, based upon the ICAO SARPs have developed their own airworthiness criteria

601.1 *Certification Authorities*

Each country has a civil certification authority. This authority can be delegated to a representative organization.

In France, for example, the Ministry of Transports through the Director General of Civil Aviation (DGAC) has this authority. In the USA the Department of Transportation (DOT) through the FAA has the same level of authority.

In Europe, the Joint Aviation Authority (JAA) has partially replaced individual national certification authorities, but countries have maintained their responsibility of airworthiness certification. Due to its status as a European Union Agency, EASA is assuming responsibilities of the JAA.

601.2 *General Organization of Regulatory Documents*

In addition to the Chicago Convention there are:

- Legislative documents defining the role and responsibilities of the services in charge of certification operations
- Technical regulations regarding certification procedures
- Technical regulations regarding applicable airworthiness standards

<table>
<tr><th rowspan="2">Country</th><th rowspan="2">International Agreements</th><th rowspan="2">Regulatory Texts</th><th colspan="2">Technical regulations</th></tr>
<tr><th>Certification Procedures</th><th>Main Airworthiness codes</th></tr>
<tr><td>USA</td><td>ICAO Convention</td><td>CFR 14</td><td>FAR 21</td><td>FAR 23 – 25 – 27 – 29
TSOs</td></tr>
<tr><td>Europe
JAA</td><td>ICAO Convention
Cyprus Convention (1990)</td><td>None</td><td>JAR 21</td><td>JAR 22 - 23 – 25 – 27 – 29 - JAR VLA – JAR VLR - JAR AWO – JAR E – JAR P – JAR APU - JAR TSOs</td></tr>
<tr><td>EU(EASA)</td><td>ICAO Convention
Cyprus Convention (1990)</td><td>Basic Regulation (CE 1592 amended by par CE 1643 et 1701)</td><td>Implementing Rules (IR) (CE 1793)</td><td>CS 22 - 23 – 25 – 27 – 29 – CS ETSO – CS E – CS P – CS AWO
CS-APU</td></tr>
<tr><td colspan="5">As an example, the last row of this table gives the regulatory texts in France prior to 28 September 2003, when EASA was officially entitled. However, during a transition period that terminates on 28 March 2007, the JAA regulatory texts remain applicable in France as long as they are not transferred and endorsed by EASA.</td></tr>
<tr><td>France (Before EASA)</td><td>ICAO Convention
Cyprus Convention (1990)</td><td>Civil Aviation Code Volume 1</td><td>RTA 1</td><td>JAR 23 – 25 – 27 – 29 – JAR E – JAR AWO – JAR APU
JTSOs</td></tr>
</table>

601.3 *International Civil Airworthiness Certification Acceptance*

Although airworthiness certification performed in one country is generally accepted internationally, there are cases when the international acceptance is questioned. Two common situations are as follows:

1. An aircraft has obtained type certification in one country and is exported to another country.
2. An aircraft is being serviced in a country other than the country of origin.

Since there are no single and worldwide airworthiness standards and certification procedures, it is necessary to assess, on a case by case basis, the potential differences and resolve potential problems.

The key to solve international acceptance problems is to have complete cooperation between authorities. For example, The JAA countries and the US FAA have signed several bilateral agreements.

602 Military Certification/Qualification

Article 3 of the Chicago Convention states:

Article 3 Civil and state aircraft
(a) This Convention shall be applicable only to civil aircraft, and shall not be applicable to state aircraft.
(b) Aircraft used in military, customs and police services shall be deemed to be state aircraft.
(c) No state aircraft of a contracting State shall fly over the territory of another State or land thereon without authorization by special agreement or otherwise, and in accordance with the terms thereof.
(d) The contracting States undertake, when issuing regulations for their state aircraft, that they will have due regard for the safety of navigation of civil aircraft.

Hence, it is not mandatory for military aircraft to hold an airworthiness certificate as defined under the Chicago Convention.

Paragraph 3d, however, stipulates that the contracting states "*will have due regard for the safety of navigation of civil aircraft*."

Civil aviation authorities are not responsible for state/military aircraft. It is the responsibility of the national ministry of defense to declare their aircraft fleet qualified for flight in civil airspace.

It should be noted that certification by a Military Aviation Authority (MAA) is generally accepted by other countries' MAA.

The following table provides country by country authority in charge of the qualification and issuing of airworthiness certificates for state aircraft.

Table 3: Overview of National Authorities for Certification of State (military) Aircraft

Country	Authority for Certification of State (military) Aircraft
Canada	The Department of National Defense has the authority for the qualification and deliverance of airworthiness certification for military state aircraft only. All other states aircraft receive airworthiness certification from the civil authority, Transport Canada.
Czech Republic	The Ministry of Defense has overall authority for military state aircraft and delegates the responsibility including certification to Military Aviation Authority.
France	The global responsibility resides in the Ministry of Defense. The qualification of an aircraft is provided under the responsibility of the Chief of Staff for the force having the ownership of the aircraft.
Germany	MOD/WTD 61 has the authority to self-certify their aircraft for operations in civil airspace at platform or equipment level. Military Authority for qualification of state aircraft: "The responsibility of the airworthiness certification of all military aircraft resides at the Head of the airworthiness branch of the Technical Center for Aircraft and Airworthiness, Manching. This center is part of the armament branch of the MOD."
Italy	The global responsibility resides within the Ministry of Defense (MOD). More in detail, the General Directorate for Aeronautical Armaments is the airworthiness certification authority for all military, police, customs and fire department aircraft.
Netherlands	The responsibility for certifying State aircraft resides with the MOD. The MOD delegates the responsibility to the Military Airworthiness Authority. The certifying method is similar to the civil method, and the standards used are similar to the civil standards.
Spain	Ministry of Defense (MoD), has authority to self-certify their aircraft for operation in civil airspace. Military Authority for qualification of state aircraft: "Military Authority for Airworthiness resides in the Spanish Ministry of Defense, (MoD). Airworthiness certificates are issued under the authority and responsibility of the Director General of Armament and Materiel, DIGAM."
Norway	The MoD has the authority to certify all national military aircrafts. This authority is delegated to the Norwegian Defense Systems Management Division

United Kingdom	Responsibility for the equivalent of civil airworthiness certification for all UK Military aircraft resides with the Secretary of State for Defense. Joint Services Publication 553 describes how this authority is delegated to the appropriate Agency for regulation of aircraft and aircraft systems for which they have responsible. Under legacy procedures, the Military Aircraft Release (MAR) is the statement that records that an acceptable Safety Case has been prepared for the aircraft and its equipment. MAR forms the basis for releasing the aircraft to service. This process is being phased out by the introduction of a Generic Aircraft Release Process which results in the confirmation of airworthiness through a Release To Service document.
United States	US DoD has overall authority for all military state aircraft and delegates this responsibility for airworthiness to each service's chief of staff.

CHAPTER 7. GPS PPS INTEGRATION OPTIONS FOR MILITARY AIRCRAFT

When considering the IFR certification of navigation systems using the GPS PPS one must first look at generic configurations to sort the issues. This chapter discusses the configuration encountered on military aircraft compared to that of civil aircraft.

701 Impact of GPS and INS coupling

The concept of INS/GPS blended systems is common in military and civilian aircraft. The widespread use of inertial systems coupled with other sensors to limit inherent drift has led to the development of several blending or hybridization techniques to take advantage of all available measurements of position and velocity. Some of the different types of hybridization between GPS and INS are described in APPENDIX B.

Although APPENDIX B provides the definition of common types of GPS/INS hybridizations, GPS and INS coupling in military aircraft must be considered on a case-by-case basis as well as the analysis of the impact on the coupling on the certification process. More information on GPS/INS coupling may be found in RTCA and EUROCAE documents, such as RTCA DO-229 & ED-75B.

702 Impact of PPS-SM, AOC and SAASM

The software used to implement PPS-SM, AOC and SAASM functionality is classified; therefore demonstration of compliance to civil standards such as RTCA DO-178B may be complicated.

Among GPS military receivers, there are today mainly two families: those receivers that incorporate the Precise Positioning Service Security Module (PPS-SM) and Auxiliary Output Chips (AOC) and those that incorporate the Selective Availability Anti-Spoofing Module (SAASM). They both have unique characteristics:

- The legacy receivers use PPS SM and AOC security modules to handle the crypto keys and access to the P(Y) code.
    - The implementation of the classified algorithms in the PPS SM and AOC is performed by the modules' manufacturer. They must bring the proof that the implementation is compliant to both DoD requirements, and development standards.
    - The interface with these security modules is accessible by US and authorized foreign GPS vendors.
- The SAASM combines the security functions under a single multi-chip module (MCM).
    - The SAASM MCM embeds chips specified by the US government (e.g. Key Data Processor (KDP)).
    - The software is loaded in the KDP by the US DoD, in a specific facility. The SAASM vendor has no access to this software.

- The direct interface with the KDP is classified "US Only." The direct interface cannot be reviewed by non-US vendors or non-US national authorities.

For legacy receivers, the proof of compliance with relevant civil standards (e.g. RTCA DO-178B or equivalent) can be brought by the GPS vendor, in cooperation with the PPS SM and AOC manufacturer if different.

Although SAASM technology provides increased security to users of GPS PPS, the new architecture does not provide the SAASM receiver vendor with complete insight into the SAASM chip set and software that was previously encountered with PPS SM and AOC. This shift has increased the difficulty in proving compliance of SAASM-based receivers to civil standards. Due to the change in secure technology, governments must work closely with SAASM receiver vendors to ensure mitigation strategies are incorporated into receiver design that will show compliance to civil standards. For example, the US is addressing the need by adding additional requirements in the MSO process ensuring GPS receiver compliance to civil standards.

703 Impact of antennas with adaptive radiation diagram

Modern anti-jam antennas (like the CRPA) with or without Advanced Digital Antenna Production (ADAP)) create nulls in the direction of jammers. In other cases a network of antennas is used to boost the antenna gain towards the satellites, this technique is known as beamforming.

When triggered by the detection of an interfering signal, the radiation diagram of the CRPA antenna is modified to create a "zero" gain towards to interference source. The location of this null in the antenna diagram will vary with the platform attitude and the respective position of the platform and the interference source. Beamforming antennas are able to actively increase their gain towards the SIS. Due to the attitude of the platform, the movement of the platform and of the satellites, the radiation diagram will never be constant.

Although CRPA antennas are more resistant to jamming, no credit can be taken for the increased performance during the certification process. Civilian standards do not take into account the potential for operation in hostile environments. Civilian GPS antenna standards are written for single frequency benign environments. There are few civilian-equivalent standards that exist for CRPA antennas, so performance credit for these antennas must be tempered. It is important for the certification authority to ensure that the performance of the CRPA antennas is 'at least as good as' civilian antennas when operating in the civil interference environment specified in the ICAO SARPs.

One example of a civilian-equivalent standard is the US Government's development of MSO-C144. Like MSO-C129 and MSO-C145, this standard was written in order to provide an equivalent level of performance to the commensurate TSOs. When software is used for nulling or beamforming it must show compliance with relevant software documents.

CHAPTER 8. AUTHORIZATION PROCESSES FOR GPS-PPS NAVIGATION USE

Safe and effective use of PPS requires State approval of the PPS SIS and PPS avionics. This chapter provides information and an example of a process that may aid States in achieving operational approval for use of PPS avionics for IFR navigation in civil airspace.

As the provider of GPS, the United States (US) Department of Defense (DoD) has developed standards for the SPS and PPS SIS. For PPS UE manufactured in the US, the US DoD has also developed PPS UE standards (e.g. Military Standard Orders (MSOs)).

801 Functional or Performance Requirements

801.1 *GPS SIS Standards.*

Because the GPS SIS is provided by a single State, the remaining States must decide to approve or disapprove use of GPS SIS (SPS and/or PPS) in their sovereign airspace.

The SPS and PPS signal specifications document the performance and other pertinent aspects of the GPS SIS. The Standard Positioning Service Performance Specification (SPS PS), Precise Positioning Service Performance Standard (PPS PS) and IS-GPS-200 are publicly releasable national documents and may be used as the basis for State approval of the GPS SIS.

The following table lists PPS SIS standards and the corresponding civil SPS SIS standards:

Table 4. Correspondence between SIS Standards

Civil SPS SIS Standard	Military PPS SIS Standard
Interface Control Document (ICD): • IS-GPS-200	Interface Control Document (ICD): • IS-GPS-200 • ICD-GPS-222 • ICD-GPS-224 • ICD-GPS-225 • ICD-GPS-227 (ICD-GPS-222, -224, -225, -227: Classified PPS Receiver Details)
Global Positioning System Standard Positioning Service Performance Standard (SPS PS)	Global Positioning System Precise Positioning Service Performance Standard (PPS PS)

801.2 *GPS PPS UE Functional or Performance Requirements - The GPSW Military Standard Order (MSO) Example*

Each State has the responsibility of developing standards and approval/certification processes for PPS UE. Alternatively, States may adopt standards and processes developed by other States or collectively develop standards and processes. Collective development may be well suited for NATO member States in Europe.

The GPSW has published Military Standard Orders (MSOs) for GPS PPS UE. These MSOs may provide the States with an example of functional and process standards that *could* be adopted for PPS UE certification.

MSOs provide a certification baseline and a basis for comparison to civil performance standards: specifically the TSOs developed by the United States FAA.

The goal of the MSO program is to produce an easily identifiable matrix of conformity with civil avionics requirements. It is well understood that all national military authorities are responsible for certifying equipment in their military airframes.

In the case of MSO in the US, the following table list PPS UE standards and the corresponding civil SPS UE standards:

Table 5. Correspondence between Avionics Standards

FAA Standard Number	RTCA Standard Number	PPS Standard Number	PPS Standard Title
TSO-C129()	DO-208	MSO-C129()	Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS) / Precise Positioning Service (PPS)
TSO-C144	DO-228	MSO-C144	Airborne Global Positioning System Antenna System
TSO-C145()	DO-229()	MSO-C145()	Airborne Navigation Sensors Using The Global Positioning System (GPS) / Precise Positioning Service (PPS) For Area Navigation (RNAV) In Required Navigation Performance (RNP) Airspace; RNP-20 RNAV Through RNP-0.3 RNAV

801.2.1 MSO-C129(), Supplemental Means Equipment

MSO-C129() documents the minimum performance standards for GPS as a supplemental means of navigation. Using the FAA's TSO-C129() as a baseline, requirements documenting PPS-unique dual frequency ionosphere corrections and encryption algorithms were added. MSO-C129() is one method the US military is using as a certification basis at the LRU level for supplemental means of navigation.

801.2.2 MSO-C144, Primary Means Antenna

MSO-C144 documents the minimum performance standards for antenna systems. Using the FAA's TSO-C144 as a baseline, requirements documenting PPS-unique dual frequency reception and optional nulling capabilities added. MSO-C144 is one method the US military is using as a certification basis for antennas in systems providing primary means of navigation (MSO-C145).

801.2.3 MSO-C145(), Primary Means Sensors

MSO-C145() documents the minimum performance standards for primary means of navigation. Using the FAA's TSO-C145 as a baseline, requirements documenting PPS-unique dual frequency ionosphere corrections and encryption algorithms were added. MSO-C145() is one method the US military is using as a certification basis at the LRU level for primary means of navigation.

801.2.4 MSOs vs. TSOs

PPS avionics standards and SPS avionics standards reference identical RTCA documents. This facilitates demonstrating military PPS standards meet or exceed the corresponding civil SPS standards. Note that while TSO-C145() requires use of the Wide Area Augmentation System (WAAS) SIS if it is available in a particular geographic region, they also provide for the SPS avionics operation when and where the WAAS SIS is unavailable. At a minimum, MSO-C145a() provides performance equivalent to TSO-C145() in areas where the WAAS signal is not available. MSO-C145() allows -- but does not require -- WAAS/SBAS SIS usage when and where the WAAS/SBAS SIS is available.

MSO-C145() requires PPS avionics to operate in three modes: (1) normal keyed PPS mode, (2) default unkeyed PPS mode, and (3) operator-commanded PPS lockout mode. In the operator-commanded PPS lockout mode, the PPS avionics retains its keys but artificially "plays dumb" by acting as if it were in the SPS mode. The primary intent of this operator-commanded PPS lock-out mode is to enable regulatory compliance in a host nation's airspace in the event that the host nation has not authorized PPS-based navigation. A secondary reason for the operator-commanded PPS lock-out mode is to provide a way for keyed PPS avionics to optionally use WAAS/SBAS signals (the data broadcast by WAAS/SBAS signals only applies to the C/A-code signal at L1). MSO-C129() also requires PPS avionics to operate in the same three modes.

801.2.5 Service Availability Prediction

Operators and their governing agencies will ensure that service availability predictions (e.g. Predictive RAIM check) are accomplished for all flights or flight segments that require use of GPS. The role of service availability prediction is to prevent losses of continuity, especially in the case of outages caused by routine satellite maintenance activities which are scheduled well in advance.

The following sections will discuss how users are notified about the different types of outages and how pilots should take advantage of service availability prediction during pre-flight planning to avoid being affected by these outages.

801.2.5.1 GPS SIS Notifications

When GPS SIS outages occur, a notification is issued to users. The notifications let users know when GPS SIS is unavailable in a particular area or from a particular satellite.

Whenever there is a change in status of a Navstar satellite, the GPS Control Segment (CS) issues a Notice Advisory to Navstar Users (NANU) and sends it to the US Coast Guard (USCG) Navigation Center (NAVCEN), to the military users and to the United States NOTAM Office (USNOF) for dissemination to the international civil aviation community.

801.2.5.2 NANUs

A NANU is an advisory message to inform users of a change in the GPS constellation, including a satellite going out of service for any reason, or return to service after a scheduled or unscheduled outage.

US Military GPS PPS users can subscribe to the NANUs at http://www.schriever.af.mil/gps. US Civil or non US GPS PPS users can subscribe at http://www.navcen.uscg.gov. Both of these web sites also post the NANUs for subsequent downloading on demand.

801.2.5.3 GPS NOTAMs

The FAA presently provides GPS NOTAMs. The FAA takes the GPS Control Segment issued NANUs and converts them into GPS NOTAMs. Publication of GPS NOTAMS allows users to deselect out-of-service satellites during a predictive RAIM check to ensure an accurate product. Satellite-specific NOTAMs encompass both SPS and PPS signals.

801.2.5.4 Predictive RAIM

Some PPS avionics include provisions to let an aircrew member determine an in-advance prediction of GPS availability at a given location and time. Predictive RAIM checks are required whenever GPS SPS is used for a flight or flight segment. This is also a requirement for use of PPS avionics. Predictive RAIM (PRAIM) checks may either be accomplished using aircraft avionics, or via other software programs during pre-flight planning.

Each nation has its own rules regarding the use of Predictive RAIM. Some nations (e.g. ECAC states) have special rules (e.g. TGL 2) for certain flight operations where Predictive RAIM is not required. Some nations provide online tools for Predictive RAIM in their airspace.

801.2.5.5 Areas of Interference

On occasion, nations conduct GPS interference tests, exercises and training activities that involve jamming of GPS receivers. These exercises help military users identify jamming effects on receivers and assess mitigation techniques to counteract these effects. These events go through a lengthy coordination process involving the local CAA, the Department/Ministry of Defense, and other government agencies.

Notification of GPS jamming testing is accomplished by NOTAM or other aeronautical information publications (e.g AIC (PINK) in the UK). For example, in the US, notification is by publishing the affected area and duration as part of the Air Route Traffic Control Center (ARTCC) or Area Control Center (ACC) NOTAMs.

801.3 *Aircraft-Level Airworthiness*

PPS avionics must be properly integrated into the aircraft in order to ensure required system level performance. Integration should comply with appropriate civil standards for GPS integration into the system architecture.

Prior to use in IFR flight, the aircraft single manager, minister of defense, or comparable authority, dependent upon the nation, must certify the airworthiness of installed PPS avionics and the associated navigation capability in a similar manner as navigation capabilities based on SPS avionics. Certification authorities must ensure the CNS/ATM certification matrices and the associated airworthiness certification processes are updated to include provisions for use of PPS avionics

801.4 *Operational Approval*

Designated military aviation authorities of each country must provide, for their own aircraft, operational approval prior to use of PPS avionics for IFR flight. This operational approval is based on development of PPS specific procedures and training, as well as maintenance and logistics procedures if applicable. At a minimum authorities will ensure crews are aware of where PPS may/must be used, how to switch between SPS and PPS (if applicable), and any differences in aircraft capabilities/limitations when using PPS.

801.5 *Host Nation Acceptance*

In accordance with ICAO Circular A32-19: Charter on the Rights and Obligations of States Relating to GNSS Services, every State preserves its authority and responsibility to control operations of aircraft and to enforce safety and other regulations within its sovereign airspace.

802 Process (Certification/Qualification) Requirements of GPS PPS Avionics

Each State has the opportunity to develop a process for certification/qualification of PPS avionics equipment and the platforms utilizing GPS PPS. For example, the United States developed the MSO process for PPS avionics that was intentionally modeled after the FAA TSO process for SPS avionics.

802.1 *Avionics (LRU/Card) Certification*

An example of avionics certification at the LRU level is the US GPS Wing certification via the MSO program. This program is briefly described in the following subsection.

802.1.1 MSO Authorization Process

Under the MSO program, the applicant (usually the manufacturer, but generalized to the entity possessing the MSO required UE technical data, control of equipment configuration, and support of avionics equipment), after suitable evaluation and testing, will certify that their product complies with minimum performance standards set forth by the MSO. The GPS Wing has delegated the implementation of the MSO program to the PPS Equipment Certification Office (PECO) located at the Los Angeles Air Force Base. The PECO reviews the applicant's statement of compliance and MSO required technical data. If compliance is found, the PECO will grant the applicant MSO authorization for their UE.

The following steps outline the general MSO process:

- Step 1 is for the applicant to determine to which MSO the avionics box will be certified.
- Step 2, after the applicant has determined which MSO approval they are seeking, the applicant should notify the PECO in writing (letter format is acceptable) that they intend to submit an application to the PECO for MSO approval. The letter should include the applicant's name, address, point of contact, and phone number. The name, part number, and software version (if applicable) of their equipment and the MSO they are seeking approval for should also be in the letter.
- Step 3, the applicant and PECO will enter into a Memorandum of Agreement (MOA) delineating responsibilities and expectations from both the PECO and applicant.
- Step 4, the applicant will submit an application (letter format is acceptable) to the PECO for the MSO approval they are seeking. The applicant will also submit a technical data package with the application. Appropriate sections of the MSO list all items necessary to complete the technical data package.
- Step 5, the PECO has 90 days from the date the application and technical data package are submitted for review to either approve or disapprove the application. Incomplete technical data packages submitted to the PECO may cause delays in the MSO approval process as the PECO may disapprove an incomplete application and ask the applicant to re-submit the application with all required technical data, resetting the 90 day review cycle. The PECO will notify the

applicant of the approval or disapproval of their application in writing. If the application is disapproved, the notification letter will inform the applicant of tasks necessary to obtain PECO approval of their product.

- Step 6, the PECO conducts a review of the applicant's manufacturing facility to insure the facility has adequate quality and process controls in place to build their product.
- Step 7, PECO issues a MSO authorization to the applicant.

802.2 *Aircraft Level Process*

Aircraft level airworthiness certification is the responsibility of the aircraft single manager, minister of defense, or comparable authority dependent upon the nation. Use of approved PPS avionics at the LRU level may simplify the certification process, but is not required if the integrated GPS PPS avionics can be demonstrated to show an equivalent level of performance and safety at the platform level. Similarly, use of specifically approved PPS antennas is not required if it can be demonstrated that the antenna provides an equivalent level of performance and safety to that demanded by civil antenna standards.

802.2.1 Non - Type Certificated Aircraft

Airworthiness certification for the use of PPS to support various navigation capabilities will be certified by the aircraft single manager, minister of defense, or comparable authority using the established airworthiness certification process. PPS avionics must be properly integrated to civil GPS integration standards (or an equivalent level of performance and safety). Aircraft certification matrices must be updated to include use of PPS avionics that meet PPS UE performance standards.

802.2.2 Type Certificated Aircraft

Certification of PPS avionics and navigation capabilities based on PPS avionics may not be covered by a FAA, JAA or EASA supplemental type certification.

- If not covered, certification of aircraft capabilities and the integration of PPS avionics is the responsibility of the aircraft single manager, minister of defense, or comparable authority dependent upon the nation.
- If covered, certified military aircraft may be considered to be operating within its supplemental certification when the GPS is operated in SPS mode. When operated in PPS, the aircraft may be operated under its supplemental type certificate depending on the civil authority or operated under the military’s self-certification authority.

803 Operational Procedures

Except as noted below, operational policy and procedures for the use of GPS outlined in country specific general flight rules manuals and instrument flight manuals apply to use of all GPS avionics, whether SPS or PPS.

803.1 *General Guidance*

The aircraft single manager, minister of defense, or comparable authority dependent upon the nation will provide operational approval prior to the IFR use of GPS PPS systems. These systems should meet the requirements and specifications similar to civil certification standards as well as, provide an equivalent level of performance and safety as determined by the applicable aviation agency and/or certification authority.

803.2 *Preflight/Mission Planning*

Military aircraft crews must confirm PPS acceptance status via the appropriate agreements prior to use in sovereign airspace. Crews are required to check all available GPS NOTAMs for the applicable route segment when GPS will be used as a primary navigation source.

Depending on Airspace and equipment, crews may need to check the RAIM availability with RAIM Prediction software, to ensure that the function is available during the different phases of the flight.

803.3 *Flight Plan Filing Procedures*

New or separate flight plan filing codes are not needed for PPS avionics. Aircraft crews should use the appropriate standard flight plan filing code when using PPS avionics in lieu of SPS avionics (e.g., /G or /W).

CHAPTER 9. TESTS AND CERTIFICATION

901 Introduction

As the purpose of this document is to give guidance on how the nations might self certify their PPS GPS receiving equipment as equivalent or better than the corresponding civil SPS GPS approved equipment it is necessary to ensure comparable assessment. Therefore, it follows that any test procedures and metrics mandated for the civil SPS equipment certification process to meet a particular TSO or equivalent should also be mandated for the PPS equipment certification process to meet the MSO. The aim should be to produce an identical documentation package in a form that would be recognizable to a civil certification authority.

902 Test Medium

Some performance testing of receiving equipment operation can be performed using live satellites but to fully check receiver functionality including the diagnosis of constellation/satellite out of tolerance limits must be approached in a different manner. Individual software modules can be tested by off-line computer modeling to check that the correct response is made to a particular input. All software within the receiver should be tested in this manner and reaction statistics generated wherever required.

At some point it will become necessary to test all the software modules together hosted by the actual hardware. This hardware in the loop simulation requires a specific GPS satellite Signal Simulator.

903 GNSS Simulator Verification

There are several manufacturers of GNSS simulators. Simulators are designed to imitate to a high degree of fidelity the SIS specification for the appropriate GNSS. Manufacturers test their own simulators’ ability to correctly mimic the chosen GNSS by simulating a number of scenarios designed to test the margins of the signal performance envelope.

Simulators tend to be validated/verified by usage. For example, simulators can be verified by comparison with results from various scenarios emulating different types of receivers. If all the results are consistent, it is generally accepted the simulator capabilities are verified. The previous example is one, but not the only way to verify a simulator’s capability (e.g. RF calibration).

904 Aircraft Certification

Although a GNSS avionics may be certified separately from the platform, platform integrators must test proper installation of avionics prior to approving airworthiness of the navigation system. The integration tests may be performed via ground or flight testing according to rules prescribed by the national military airworthiness authority.

GLOSSARY OF ABBREVIATIONS

The Glossary contains abbreviations and acronyms in this publication.

AAIM	Aircraft Autonomous Integrity Monitoring
ABAS	Aircraft Based Augmentation System
ACC	Area Control Center
ACG/5	Aerospace Capability Group 5
ADAP	Advanced Digital Antenna Production
ADF	Automatic Direction Finder
ADS	Automatic Dependent Surveillance
AIC	Aeronautical Information Circular
ALS JWG	(NATO) Approach and Landing Systems Joint Working Group
ANP	Allied Navigation Publication
AOC	Auxiliary Output Chip
APV	Approach with Vertical Guidance
ARINC	Aeronautical Radio Inc.
ARTCC	Air Route Traffic Control Center
ARNS	Aeronautical Radio Navigation Service
ATM	Air Traffic Management
BOC	Binary Offset Carrier
B-RNAV	Basic RNAV
CAA	Civil Aviation Authority
C/A	Coarse/Acquisition
CNS/ATM	Communication Navigation & Surveillance / Air Traffic Management
CDMA	Code Division Multiple Access
CRPA	Controlled Reception Pattern Antenna
CS-ETSO	Certification Specification for European Technical Standard Order
CS	Control Segment
CSA	Channel of Standard Accuracy
DGAC	Director General of Civil Aviation (France)
DGPS	Differential GPS
DME	Distance Measuring Equipment
DoD	(United States) Department of Defense
DOT	(United States) Department of Transportation
DSE	Display System Error
DT&E	Developmental Test & Evaluation
EASA	European Aviation Safety Authority
EC	European Commission
ECAC	European Civil Aviation Community

ECM	Electronic Countermeasures
EGNOS	European Geostationary Navigation Overlay Service
ESA	European Space Agency
ESM	Electronic Support Measures
EUROCAE	EUROpean Organization of Civil Aviation Equipment manufacturers
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FD	Fault Detection
FDE	Fault Detection & Exclusion
FDMA	Frequency Division Multiple Access
FMS	Flight Management System
FOUO	For Official Use Only
FRPA	Fixed Reception Pattern Antenna
FTE	Flight Technical Error
GAGAN	GPS Aided GEO Augmented Navigation
GATM	Global Air Traffic Management
GBAS	Ground based Augmentation System
GEO	Geostationary Earth Orbit
GLONASS	GLObal NAvigation Satellite System
GNSS	Global Navigation Satellite System
GNSSP	GNSS Panel
GPS	Global Positioning System
GPSW	GPS Wing
GRAS	GPS Regional Augmentation System
HAL	Horizontal Alert Limit
HAT	Height Above Threshold
IAW	In Accordance With
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
IFR	Instrument Flight Rules
ILS	Instrument Landing System
INS	Inertial Navigation System
IOC	Initial Operational Capability
IS	Interface Specification
JAA	Joint Aviation Authority
JPALS	Joint Precision Approach & Landing System
JPO	Joint Program Office (predecessor to the GPS Wing (GPSW))
KDP	Key Data Processor
LAAS	Local Area Augmentation System
LADGPS	Local Area Differential GPS
LRU	Line Replaceable Unit

MAA	Military Aviation Authority
MAGR	Miniaturized Airborne GPS Receiver
MAR	Military Aircraft Release
MCM	Multi-chip Module
MEO	Medium Earth Orbit
MOA	Memorandum of Agreement
MOD/MoD	Ministry of Defense
MOPS	Minimum Operation Performance Standards
MOU	Memorandum of Understanding
MSAS	Ministry of Transport Satellite (MTSAT) Satellite Augmentation System
MSO	Military Standard Order
NAC	North Atlantic Council
NAFAG	NATO Air Force Armaments Group
NANU	Notice Advisory to Navigation Users
NAS	National Airspace
NATO	North Atlantic Treaty Organization
NAVCEN	(USCG) Navigation Center
NAVWAR	Navigation Warfare
NC3B	NATO C3 Board
NOTAM	Notice to Airman
nm	nautical miles
NPA	Non-Precision Approach
NSE	Navigation System Error
NSP	Navigation Systems Panel (ICAO Sub-panel)
OT&E	Operational Test & Evaluation
P-RNAV	Precision RNAV
PDE	Path Definition Error
PECO PPS	Equipment Certification Office
PNT	Positioning, Navigation and Timing
PPS	Precise Positioning Service
PPS-LO	PPS Lock put
PPS-SM	Precise Positioning Service Security Module
PRAIM	Predictive RAIM
PRN	Psuedorandom Noise
PRS	Public Regulated Service
PS	Performance Standard
PVT	Positioning, Velocity and Timing
QZSS	Quasi Zenith Satellite System
RAIM	Receiver Autonomous Integrity Monitoring
RF	Radio Frequency
RNAV	Area Navigation
RNP	Required Navigation Performance

SA	Selective Availability
SAASM	Selective Availability Anti-spoofing Module
SARPs	Standards and Recommended Practices
SBAS	Space Based Augmentation System
SC/8	(NATO C3 Board Navigation) Sub-Committee 8
SIPRNET	Secret IP Router Network
SIS	Signal In Space
SOL	Safety of Life
SPS	Standard Positioning Service
STANAG	Standardization Agreement
SUA	Special Use Airspace
TA-12	(Trimble) Tasman ARINC-12 (GPS Receiver)
TACAN	Tactical Navigation
TSE	Total System Error
TSO	Technical Standard Order
UE	User Equipment
US	United States
USCG	United States Coast Guard
USNOF	United States NOTAM Office
VAL	Vertical Alert Limit
VHF	Very High Frequency
VOR	VHF Omni Range
WAAS	Wide Area Augmentation System

APPENDIX A. Countries Authorizing Use of GPS SPS In Civil Airspace

States	Use of GPS	As of Date	Source	Remarks
A				
Afghanistan	NPA	July 2005	ICAO	
Albania	En-route	September 2003	EUROCONTROL	
Angola	En-route to NPA	September 2005	ICAO	Pending, procedures tested but not yet published
Anguilla	En-route to departure	June 2003	ICAO	
Antigua and Barbuda	En-route to departure	June 2003	ICAO	
Argentina	Primary means of navigation	May 2005	ICAO	
Armenia	En-route	September 2003	EUROCONTROL	
Australia	Oceanic and remote	November 2005	Australia CASA	
Austria	En-route to terminal	October 2003	Republic of Austria Aeronautical Information Service	
Azerbaijan	En-route to NPA	September 2003	EUROCONTROL	
B				
Bahamas	En-route to terminal	November 2001	ICAO	
Barbados	En-route to departure	June 2003	ICAO	
Belgium	En-route to terminal	September 2003	EUROCONTROL	
Benin	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
Bhutan	NPA	July 2006	ICAO	Procedures developed for NPA as supplemental means
Bolivia	Supplementary means	May 2005	ICAO	

States	**Use of GPS**	**As of Date**	**Source**	**Remarks**
	of navigation			
Bosnia and Herzegovina	En-route	September 2003	EUROCONTROL	
Botswana	En-route to NPA	September 2005	ICAO	Procedures tested but not yet published
Brazil	Supplementary means of navigation	May 2005	ICAO	
Brunei Darussalam	NPA	March 2005	ICAO	NPA as supplemental means planned for 2003
Bulgaria	En-route	September 2003	EUROCONTROL	
Burkina Faso	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
C				
Cameroon	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
Canada	En-route to NPA	August 2006	NAV Canada	
Cape Verde	En-route to NPA	September 2005	ICAO	
Cayman Islands	En-route to terminal	November 2001	ICAO	
Central African Republic	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
Chad	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
Chile	Primary means of navigation	May 2005	ICAO	
China	En-route	July 2006	ICAO	
Hong Kong, China	En-route	July 2006	ICAO	
Colombia	Supplementary means of navigation	May 2005	ICAO	

States	Use of GPS	As of Date	Source	Remarks
Congo	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
Cook Island	NPA	October 2005	CAA New Zealand	
Costa Rica	En-route to terminal	November 2001	ICAO	
Cote d'Ivoire	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
Croatia	En-route to terminal	September 2003	EUROCONTROL	
Cuba	En-route to terminal	November 2001	ICAO	
Cyprus	En-route to NPA	September 2003	EUROCONTROL	
Czech Republic	En-route to terminal	September 2003	EUROCONTROL	
D				
Democratic Republic of Congo	En-route to NPA	September 2005	ICAO	Procedures tested but not yet published
Denmark	En-route to terminal	December 2003	EUROCONTROL	
Dominican Republic	En-route to terminal	November 2001	ICAO	
E				
Ecuador	En-route as supplementary mean	February 2006	DGAC Ecuador	
Egypt	En-route to NPA	September 2005	ICAO	
El Salvador	En-route to NPA	September 2003	ICAO	
Equatorial Guinea	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
Estonia	En-route to terminal	September 2003	ICAO	

States	Use of GPS	As of Date	Source	Remarks
Ethiopia	En-route to NPA	September 2005	ICAO	
F				
Fiji	En-route to NPA	July 2006	ICAO	
Finland	En-route to terminal	September 2003	EUROCONTROL	
France	En-route to terminal	July 2004	EUROCONTROL	
G				
Gambia	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
Gabon	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
Georgia	En-route	April 2005	EUROCONTROL	
Germany	En-route	September 2003	EUROCONTROL	
Greece	En-route to terminal	February 2006	CAA	
Grenada	En-route to departure	June 2003	ICAO	
H				
Haiti	En-route to NPA	September 2003	ICAO	
Honduras	En-route to terminal	November 2001	ICAO	
Hungary	En-route	September 2003	EUROCONTROL	
I				
Iceland	En-route	September 2003	EUROCONTROL	
India	En-route	July 2006	ICAO	SBAS, technical developments in 2007 and implementation planned for 2009

States	**Use of GPS**	**As of Date**	**Source**	**Remarks**
Indonesia	NPA	July 2006	ICAO	Procedures to be completed in 2006 for NPA supplemental means
Ireland	En-route to terminal	October 2003	Irish Aviation Authority	
Italy	En-route to terminal	March 2004	AIP Italia AIC A3/2004	
J				
Japan	Supplemental means for instrument flight procedures	August 2003	ICAO	
Jamaica	En-route to terminal	November 2001	ICAO	
K				
Kenya	En-route to NPA	September 2005	ICAO	
L				
Lao PDR	En-route	July 2006	ICAO	
Latvia	En-route	September 2003	EUROCONTROL	
Lesotho	En-route to NPA	September 2005	ICAO	Procedures tested but not yet published
Lithuania	En-route	September 2003	EUROCONTROL	
Luxembourg	En-route	September 2003	EUROCONTROL	
M				
The former Yugoslav Republic of Macedonia	En-route	September 2003	EUROCONTROL	
Madagascar	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts

States	Use of GPS	As of Date	Source	Remarks
				not yet published
Malawi	En-route to NPA	September 2005	ICAO	
Malaysia	NPA	July 2006	ICAO	NPA as supplemental means at KLIA planned for 2003
Maldives	En-route	July 2006	ICAO	Trials planned as en-route supplemental means for 2005-2008, implementation in 2008
Mali	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
Malta	En-route to terminal	October 2003	CAA AIC A05/03	
Marshall Island	NPA	July 2006	ICAO	
Mauritania	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
Mauritius	En-route to NPA	September 2005	ICAO	Procedures tested but not yet published
Mexico	En-route to NPA	March 2006	ICAO	
Micronesia Federated States of				
Chuuk	NPA	July 2006	ICAO	
Kosrae	NPA	July 2006	ICAO	
Pohnpei	NPA	July 2006	ICAO	
Yap	NPA	July 2006	ICAO	
Moldova	En-route	September 2003	EUROCONTROL	
Mongolia	En-route to NPA	July 2006	ICAO	
Morocco	En-route	April 2003	Portugal CAA	
Monaco	En-route	September 2003	EUROCONTROL	
Mozambique	En-route to NPA	September	ICAO	Procedures tested but

States	Use of GPS	As of Date	Source	Remarks
		2005		not yet published
N				
Namibia	En-route to NPA	September 2005	ICAO	Procedures tested but not yet published
Nepal	En-route to NPA	July 2006	ICAO	
Netherlands	En-route to terminal	September 2003	ICAO	
New Zealand	NPA	July 2006	ICAO	
Niger	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
Niue	NPA	October 2005	ICAO	
Norway	En-route to terminal	September 2003	EUROCONTROL	
P				
Pakistan	En-route to NPA	July 2006	ICAO	Arrival and departure NPA procedures as supplemental means are being developed. En-route as primary/supplemental means is planned for 2005-2010
Palau	Use of GPS is approved for aircraft navigation purposes	May 1999	IBAC	
Panama	Supplementary means of navigation	May 2005	ICAO	
Paraguay	Supplementary means of navigation	May 2005	ICAO	
Peru	Supplementary means of navigation	May 2005	ICAO	
Philippines	NPA	January 2002	ICAO	Aircraft operations procedures (non-precision approaches) based on GPS and WGS-84 will be established at an early

States	Use of GPS	As of Date	Source	Remarks
				stage before application of SBAS in 2005
Poland	En-route	September 2003	EUROCONTROL	
Portugal	En-route to terminal	September 2003	EUROCONTROL	
R				
Romania	En-route to terminal	February 2005	EUROCONTROL	
S				
Samoa	NPA	October 2005	CAA New Zealand	
Senegal	En-route	September 2005	ICAO	Procedures published but regulatory texts not yet published
Serbia and Montenegro	En-route	September 2003	EUROCONTROL	
Seychelles	En-route to NPA	September 2005	ICAO	Procedures tested but not yet published
Singapore	En-route to NPA	July 2006	ICAO	
Slovak Republic	En-route to terminal	September 2003	EUROCONTROL	
Slovenia	En-route to terminal	January 2004	EUROCONTROL	
South Africa	En-route to NPA	September 2005	ICAO	
Spain	En-route to terminal	September 2003	EUROCONTROL	
Sri Lanka	En-route to NPA	July 2005	ICAO	NPA as supplemental means planned for 2005. GPS based domestic route structure being developed.
St. Kitts and Nevis	En-route to departure	June 2003	ICAO	
St. Lucia	En-route to departure	June 2003	ICAO	
St. Vincent and	En-route to departure	June 2003	ICAO	

States	**Use of GPS**	**As of Date**	**Source**	**Remarks**
Grenadines				
Sudan	En-route to NPA	September 2005	ICAO	
Suriname	Primary means of navigation	May 2005	ICAO	
Swaziland	En-route to NPA	September 2005	ICAO	Procedures tested but not yet published
Sweden	En-route to terminal	September 2003	EUROCONTROL	
Switzerland	En-route to terminal	August 2004	EUROCONTROL	
T				
Thailand	En-route	July 2006	ICAO	
Tanzania	En-route to NPA	September 2005	ICAO	Procedures tested but not yet published
Togo	En-route to NPA	September 2005	ICAO	Procedures published but regulatory texts not yet published
Tonga	NPA	July 2006	ICAO	NPA planned for 2007
Trinidad and Tobago	En-route to departure	June 2003	ICAO	
Tunisia	En-route to NPA	September 2005	ICAO	
Turkey	En-route to terminal	December 2003	EUROCONTROL	
U				
Ukraine	En-route	September 2003	EUROCONTROL	
United Arab Emirates	En-route to terminal	May 1998	UAE General Civil Aviation Authority	
United Kingdom	Supplemental Means for En-route to terminal	October 2003	EUROCONTROL	
United States of America	En-route to NPA	February 1996	FAA	
Uruguay	Primary means of navigation	May 2005	ICAO	

States	Use of GPS	As of Date	Source	Remarks
V				
Vanuatu	NPA	July 2005	Vanuatu Civil Aviation Authority	
Venezuela	Primary means of navigation	May 2005	ICAO	
Viet Nam	En-route to NPA	July 2005	ICAO	Planned for NPA as supplemental means for 2004. Implementation as en-route supplemental means planned for 2004
Z				
Zambia	En-route to NPA	September 2005	ICAO	Procedures tested but not yet published
Zimbabwe	En-route to NPA	September 2005	ICAO	Procedures tested but not yet published

APPENDIX B. Additional Information on GPS Integration Architectures

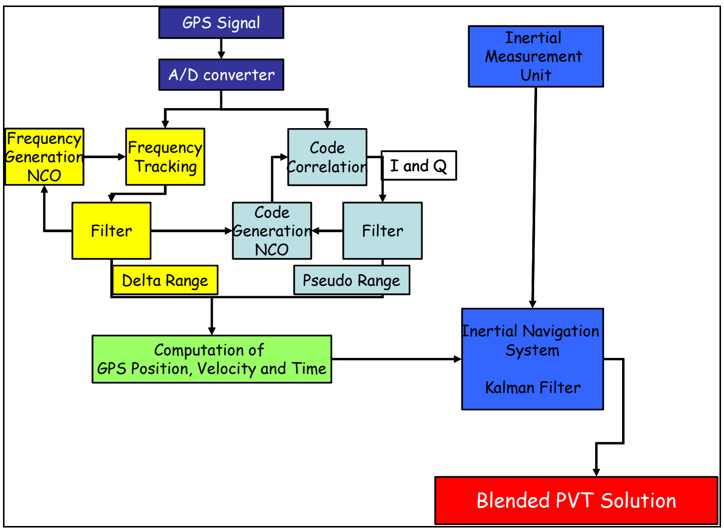
The concept of INS/GPS systems is very common in military aircraft. This concept can be summarized as being the most efficient way to use the accurate, but susceptible to interferences, GPS PPS fixes and the drifting, but low noise and interference immune, inertial navigation.

The blending of these measurements (along with others like baro-altimeters for example) can take many different forms, each one being composed of variants. The progression from the loose coupling to the deep integration was made possible by the augmentation of computation capabilities to handle huge workloads in smaller and smaller volumes. The more sophisticated is your blending technique, the more resistance you gain to interference signals.

There can be considered three classes of hybridization between GPS and Inertial sensors: loose coupling, tight coupling and ultra tight coupling also called deep integration.

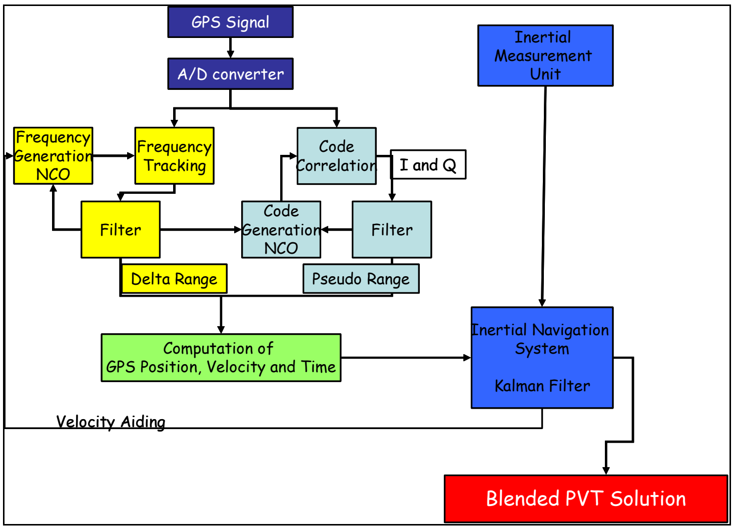
B.1 Loose Hybridization, No Velocity Aiding at the Receiver Level

This case is almost equivalent to the stand alone receiver because the receiver computes position and velocity. Those fixes are transmitted at regular intervals to update the navigation filter of the Inertial Navigation System. But, there is no feedback from the filter to the GPS receiver.



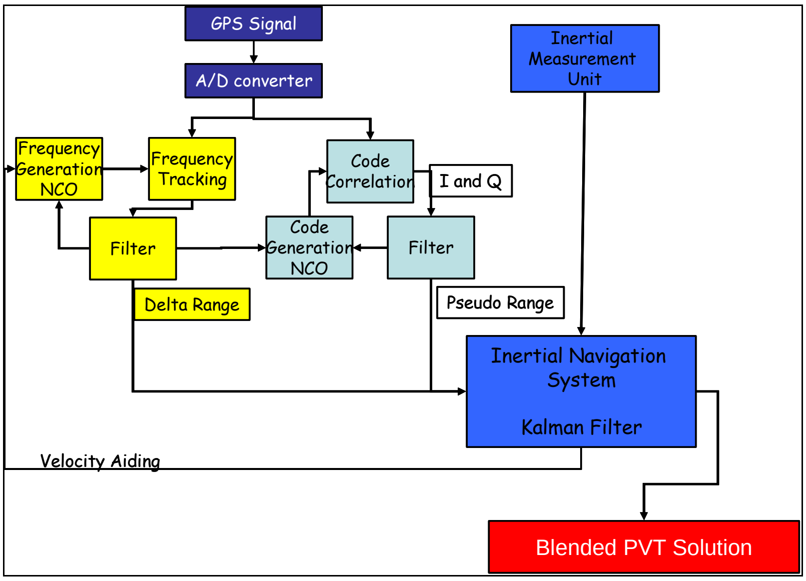
B.2 Loose Hybridization, with Velocity Aiding of the GPS PPS Receiver

This case is slightly different from the previous one, because the Inertial Navigation System provides some aiding to the receiver to supplement the phase loop that may be disturbed by interfering signals.



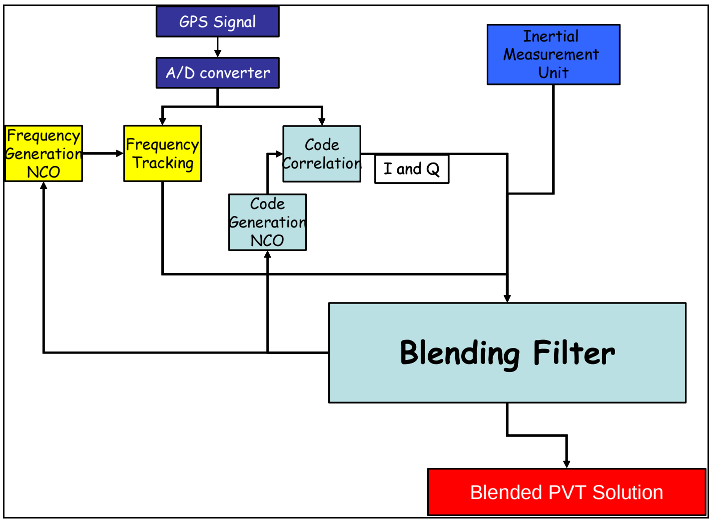
B.3 Tight Hybridization

For tight hybridization, the coupling of the GPS receiver and the INS filter is much stronger. The GPS receiver does not compute any position or velocity solution. For each satellite, the Pseudo Range and Delta Range are calculated and sent directly to the Kalman navigation filter which blends them with information from the other sensors to compute a final position and velocity. Under normal conditions, the GPS has a strong weight in the final solution, but when interfering signals are present it will be different. The navigation filter will optimize the solution depending on the noise characteristics at the time of measurement.



B.4 Ultra Tight Hybridization

For this technique of blending, the receiver itself has a very low workload. The phase and code loops for each satellite are in fact included in a much larger filter, outside of the GPS receiver, that federates the measurements from all other available sensors (inertial and other sensors). The result is that the GPS code and phase loops are closed by this filter to maintain the tracking of the satellite signals.



LIST OF EFFECTIVE PAGES
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