# DEPARTMENT OF TRANSPORTATION

# GLOBAL POSITIONING SYSTEM (GPS) CIVIL MONITORING PERFORMANCE SPECIFICATION

Thomas J. Nagle, DOT/FAA
Program Manager, Civil Applications
NAVSTAR, Global Positioning System
GPS Joint Program Office
2420 Vela Way, Suite 1866
El Segundo, CA 90245-4659

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## Executive Summary

This document is published and maintained at the direction of the Program Manager for Civil Applications, Global Positioning System Joint Program Office (GPS JPO). It defines detailed requirements for monitoring of the GPS civil service and signals based on top level requirements to monitor all signals all of the time. Upon approval it will be used by the GPS community to determine adequacy of civil monitoring in its present state and to develop focus for improved monitoring solutions.

The GPS Civil Monitoring Performance Specification (CMPS) defines a set of metrics for measuring GPS performance against standards defined in official U.S. Government documents such as the Standard Positioning Service Performance Standard, the Navstar GPS Space Segment/Navigation User Interfaces (IS-GPS-200), and Navstar GPS Space Segment/User Segment L5 Interfaces (IS-GPS-705). This document will be revised to track changes in these reference documents. The implementation of a system that fulfills these requirements will allow operators and users to verify that civil GPS performance standards are being achieved. To the extent practicable, each metric defined is traceable to one or more specifications of performance listed above. In cases where the metric is an indirect measurement of the performance, the connection between the metric and the standard is explained and the threshold and/or goal necessary to achieve acceptable performance provided.

This document also defines the scope and range of monitoring needs not traceable to the above documents but reasonably expected by civil users. These include the ability of the service to detect defects in signal and data, the need to rapidly report anomalous service behavior to satellite operators for resolution, and notification to users of the causes and effects of such anomalies for their various service types (e.g., positioning, timing, and navigation). The document also addresses the need for archives of key data and events to support future improvements in GPS service and to respond to external queries about past GPS service levels.

The performance specification addresses the current L1 C/A signal and the GPS Standard Positioning Service (SPS) provided via that signal. It also includes the planned L2C and L5 signals.

The performance specification is not intended to state how civil monitoring will be implemented nor does it address monitoring system architecture. The purpose of this document is to provide a compilation of current requirements for monitoring of the civil service and signals that can be used by the U.S. Government in planning future GPS development efforts.

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# 1 SCOPE

## 1.1 SCOPE

This performance specification establishes the performance and verification requirements for GPS civil monitoring.

## 1.2 BACKGROUND

Global Positioning System (GPS) was not originally envisioned to be a worldwide civil utility. It was created as a military navigation system, and was designed to meet warfighter needs. As a result, the service provider monitors only the Precise Positioning Service (PPS). The service provider has never continuously monitored the Standard Positioning Service (SPS) signal. Indeed, the Coarse/Acquisition (C/A) code has only recently been monitored by the service provider for a brief time after the satellites rise above the horizon of each GPS monitor station and initial acquisition is in progress.

It was not until 1983 that the U.S. Government redefined the mission of GPS to include international civil users. In that year, a Korean airliner drifted off course and was shot down by the Soviet Union when it allegedly flew over restricted airspace. Soon after, President Reagan's Administration issued a statement saying that GPS would be available for international civil use. Not until 1996 was this formalized when President Clinton declared through Presidential Decision Directive ("U. S. Global Positioning System Policy") that GPS was a civil and military service, to be provided on a continuous worldwide basis free of direct user fees. This was later codified in United States Code (USC), Title 10, Section 2281.

Until May 2000, the GPS service provider intentionally degraded the SPS signal in an effort to deny accurate positioning service to U.S. military adversaries. Removing the degradation of SPS stimulated increased use and dependence on the SPS signal. Adding a second and third civil signal (L2C and L5) will further increase civil reliance on GPS. The increased size of the user community argues for greater importance of monitoring, while the increased accuracy of the service implies that monitoring will be more challenging.

Through the GPS SPS Performance Standard (SPSPS), the U.S. Government establishes a basis for the level of service for civil users. The document states that one of its objectives is to "identify performance standards the U.S. Government uses to manage SPS performance." It also notes that "The U.S. Government intends to assess ways for improving its GPS monitoring and measurement capabilities…" This performance specification is a means of identifying the desired monitoring capabilities.

The military/government use of GPS represents but a small fraction of the total market; civil applications represent the vast majority and have an estimated dollar amount approaching $16 billion for 2003 [Department of Commerce brief, February 2001]. GPS serves many expanding and emerging commercial markets: aviation, precision farming, survey and mapping, maritime, scientific, timing, embedded wireless, space navigation, and terrestrial navigation, to name a few. Additionally, GPS-based safety, security, navigation and information systems will play a major role in the implementation of the Intelligent Transportation System (ITS) and other telematic

systems of the future. GPS's growing integration in safety-of-life applications alone compels that the basic SPS service be adequately monitored to ensure compliance with minimal standards.

### 1.3 DOCUMENT DESCRIPTION

The purpose of civil monitoring is to ensure civil GPS performance standards are being achieved, aid the satellite operators in minimizing adverse impacts to users, and assess the level of performance of the GPS. Civil monitoring is not intended to provide application specific monitoring, such as those employed in providing safety of life integrity monitoring services.

In support of its objectives, the performance specification provides a set of metrics for measuring GPS performance against standards defined in U.S. Government policy and high-level system definitions relevant to civil users. These include the Federal Radionavigation Plan, the Standard Positioning Service Performance Standard, the Navstar GPS Space Segment/Navigation User Interfaces (IS-GPS-200), and Navstar GPS Space Segment/User Segment L5 Interfaces (IS-GPS-705). To the extent practicable, each metric defined is traceable to one or more specifications of performance. In cases where the metric is an indirect measurement of the performance, the connection between the metric and the standard is explained and the threshold and/or goal necessary to achieve acceptable performance provided.

This document also defines the scope and range of monitoring needs not otherwise documented but reasonably expected by civil users. These include the ability of the service to detect defects in signal and data, the need to rapidly report anomalous service behavior to satellite operators for resolution, and notification to users of the causes and effects of such anomalies for their various service types (e.g., positioning, timing, and navigation).

It is important to note that the SPSPS defines only one civil service associated with GPS. That service is the SPS delivered via the L1 C/A code. The word "service" should be interpreted to mean the L1 C/A SPS. At the same time, it is recognized that there are a variety of means for using GPS beyond the official definition of SPS. While it is beyond the scope of this document to attempt to define new classes of service, it is possible to define monitoring criteria on a signal-by-signal basis. In this document, it is assumed that users implementing approaches beyond basic GPS have (or will) base their GPS implementations on the signal specifications contained in the referenced documents (specifically the IS-GPS-200 and IS-GPS-705). Based on that assumption, the performance specification defines signal monitoring requirements for L1 C/A, L2C, and L5 that assure the signal specifications are being met based on the signal descriptions in these interface documents.

There are some performance metrics that are known to be of interest, but could not be included in the current draft of this document while remaining within the definitions in existing policy and system documentation. Examples of such items include metrics associated with user range rate error, user acceleration error, and evaluation of performance in the Space Service volume. It is anticipated that metrics associated with these items will be included in future revisions of this document as policy evolves and the appropriate source documents are updated.

The metrics defined in the performance specification will be of immediate use to the GPS service provider (the U.S. Air Force) and to agencies such as the U.S. Coast Guard Navigation Center

and the FAA National Operations Control Center that have responsibility for communicating with GPS end users. All users will benefit from: (1) reduced outage times by timely notification to the GPS operators when anomalies occur; and (2) long-term assurance that U.S. Government commitments regarding GPS service levels are consistently being met.

In addition, this document addresses the need to assess the level of performance of the civil services, even when the services are performing better than the standards. This includes requirements for archives of key data and events to support future improvements in GPS service and to respond to external queries about past GPS service levels.

The requirements presented in Section 3 represent the monitoring requirements related to the SPS and the GPS signals used by the civil community. While some of these requirements are only of interest to the civil community, many of them are of equal interest to the military. For example: (1) the requirements associated with constellation management are applicable to both groups; (2) the requirements associated with L1 C/A are of interest to the military due to the large number of legacy user equipment receivers that require L1 C/A in order to acquire the PPS; and (3) the requirements associated with L5 are of interest to military to support aviation users that support military missions (both civil and military aircraft). Therefore, there is a significant amount of overlap between the civil monitoring requirements and those of general interest. This is illustrated in Figure 1-1.

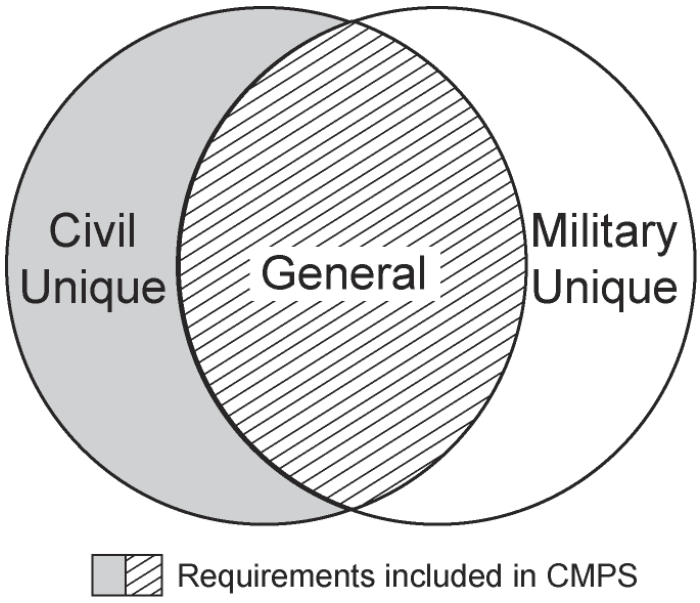


**Figure 1-1 – Partitioning of Monitoring Requirements**

This partitioning of requirements may have practical implications. In the current "U.S. Space-Based Positioning, Navigation, and Timing Policy", it is noted that "*…civil signal performance monitoring…will be funded by the agency or agencies requirement those services or capabilities, including out-year procurement and operations costs.*" Therefore, funding for the development and operation of monitoring capabilities may fall under the jurisdiction of different organizations

depending on whether the requirement is related to a particular user community or is perceived to be of general importance.

To illustrate how the requirements from Section 3 may be partitioned, Section 4 contains a table that partitions the requirements into civil-unique and general categories.

This document is not intended to state how civil monitoring will be implemented nor will it address monitoring system architecture. In particular, no assumption is made regarding the level of automation of the service. The purpose of this document is to provide a comprehensive compilation of civil monitoring requirements.

# 2 APPLICABLE DOCUMENTS

## 2.1 GENERAL

This section lists source documents for the requirements delineated in Sections 3 and 4.

## 2.2 GOVERNMENT DOCUMENTS

### 2.2.1 Specifications, standards and handbooks

| | |
|---|---|
| IS-GPS-200D<br>7 December 2004 | Navstar GPS Space Segment/Navigation User Interfaces |
| IS-GPS-705, IRN 001, 002<br>20 April 2005 | Navstar GPS Space Segment/ User Segment L5 Interfaces |
| October 2001 | Global Positioning System Standard Positioning Service Performance Standard |

### 2.2.2 Other Government documents, drawings, and publications

| | |
|---|---|
| DOT-VNTSC-RSPA-01-3 | 2001 Federal Radionavigation Plan |
| DOD-4650.5 | |
| | Memorandum of Agreement, between the Department of Defense and the Department of Transportation, Civil Use of the Global Positioning System, January 8, 1993 |
| | Memorandum of Agreement between the Department of Defense and the Department of Transportation, Civil Use of the Global Positioning System, Annex 3: Information Coordination and Dissemination, July 15, 1999 |

## 2.3 NON-GOVERNMENT DOCUMENTS

None

# 3 REQUIREMENTS

Except where specifically noted, civil monitoring shall meet the requirements stipulated herein. The origin of each requirement is identified inside square brackets following the statement of the requirement. For the purposes of identifying the origin of the requirements, the following abbreviations are used

- SPSPS – Standard Positioning Service Performance Standard
- IS-GPS-200 – Navstar GPS Space Segment/Navigation User Interfaces
- IS-GPS-705 – Navstar GPS Space Segment/ User Segment L5 Interfaces

System attributes used in defining the requirements in this section are based on the definitions found in Section 4.4.

## 3.1 SYSTEM PERFORMANCE MONITORING REQUIREMENTS

All monitoring requirements defined in Sections 3.1.1 through 3.1.4 refer to the SPS as defined in the October 2001 GPS SPSPS.

### 3.1.1 Verification of Constellation Management Standard

The following monitoring requirements apply to satellites transmitting standard code and indicating "healthy" in the broadcast navigation message. Civil monitoring shall verify that:

a. the Groundtrack Equatorial Crossing of each active GPS satellite is within $2^{o}$ of the value provided in Table 3.1-1 [SPSPS Section 3.1],
b. the semi-major axis of each active GPS satellite is within +/-50 km for Block IIR or +/-17km for Block II/IIA [SPSPS Section 3.1],
c. the percentage of time over a 24-hour period that 24 operational satellites are available on orbit is greater than or equal to 0.95 [SPSPS Section 3.2], and
d. the percentage of time over a one year period that 21 satellites in the nominal plane/slot positions and set healthy and broadcasting a navigation signal is greater than or equal to 0.98 [SPSPS Section 3.2].

**Table 3.1.-1 – Reference Orbit Slot Assignments as of the Defined Epoch**

| SLOT | RAAN | Argument of Latitude | SLOT | RAAN | Argument of Latitude |
|---|---|---|---|---|---|
| A1 | 272.847° | 268.126° | D1 | 92.847° | 135.226° |
| A2 | 272.847° | 161.786° | D2 | 92.847° | 265.446° |
| A3 | 272.847° | 11.676° | D3 | 92.847° | 35.156° |
| A4 | 272.847° | 41.806° | D4 | 92.847° | 167.356° |
| B1 | 332.847° | 80.956° | E1 | 152.847° | 197.046° |
| B2 | 332.847° | 173.336° | E2 | 152.847° | 302.596° |
| B3 | 332.847° | 309.976° | E3 | 152.847° | 66.066° |
| B4 | 332.847° | 204.376° | E4 | 152.847° | 333.686° |
| C1 | 32.847° | 111.876° | F1 | 212.847° | 238.886° |
| C2 | 32.847° | 11.796° | F2 | 212.847° | 345.226° |
| C3 | 32.847° | 339.666° | F3 | 212.847° | 105.206° |
| C4 | 32.847° | 241.556° | F4 | 212.847° | 135.346° |

EPOCH: 0000Z, 1 July 1993
GREENWICH HOUR ANGLE: $18^{h}\ 36^{m}14.4^{s}$
REFERENCED TO FK5/J2000.00 COORDINATES

### 3.1.2 Verification of Service Availability Standard

The following monitoring requirements apply to satellites transmitting standard code and indicating "healthy" in the broadcast navigation message. Civil monitoring shall verify that:

a. the percentage of time the constellation's global Position Dilution of Precision (PDOP) value is 6 or less is greater than or equal to 98% within the service volume over any 24-hour interval [SPSPS Section 3.2],
b. the percentage of time the constellation's worst site PDOP value is 6 or less is greater than or equal to 88% within the service volume over any 24-hour interval [SPSPS Section 3.2],
c. verify that availability 95% horizontal accuracy of 36 meters is greater than or equal to 99% in any 24-hour interval for an average location within the service volume considering only the SIS component of accuracy [SPSPS Section 3.2],
d. availability 95% vertical accuracy of 77 meters is greater than or equal to 99% in any 24-hour interval for an average location within the service volume considering only the SIS component of accuracy [SPSPS Section 3.2],
e. availability 95% horizontal accuracy of 36 meters is greater than or equal to 90% in any 24-hour interval at the worst-case location in the service volume considering only the SIS component of accuracy [SPSPS Section 3.2], and
f. availability 95% vertical accuracy of 77 meters is greater than or equal to 90% in any 24-hour interval at the worst-case location in the service volume considering only the SIS component of accuracy [SPSPS Section 3.2].

### 3.1.3 Verification of Service Reliability Standard

The following monitoring requirements apply to satellites transmitting standard code and indicating "healthy" in the broadcast navigation message. Civil monitoring shall verify that:

a. the percentage of time the Standard Positioning Service Signal in Space User Range Error is 30 meters or less with daily percentage values averaged over a year is greater than or equal to 99.94% [SPSPS Section 3.3],
b. the percentage of time the Standard Positioning Service Signal in Space User Range Error is 30 meters or less for the worst-case point within the service volume with daily percentage values averaged over a year is greater than or equal to 99.79% [SPSPS Section 3.3], and
c. verify that the probability of hazardously misleading information (HMI) events (over a one year period) is less than 0.002 [SPSPS Section 3.3].

### 3.1.4 Verification of Accuracy Standard

The following monitoring requirements apply to satellites transmitting standard code and indicating "healthy" in the broadcast navigation message. Civil monitoring shall verify that:

a. the average of the constellation's individual satellite Signal in Space Standard Positioning Service root mean square User Range Error over any 24-hour period for any point in the service volume is less than or equal to 6 meters [SPSPS Section 3.4],
b. the global average horizontal positioning domain accuracy measured over a 24-hour interval is less than or equal to 13 meters 95% considering only a signal in space errors and using an all-in-view receiver algorithm [SPSPS Section 3.4],
c. the global average vertical positioning domain accuracy measured over a 24-hour interval is less than or equal to 22 meters 95% considering only a signal in space errors and using an all-in-view receiver algorithm [SPSPS Section 3.4],
d. the horizontal positioning domain accuracy for the worst site in the service volume measured over a 24-hour interval is less than or equal to 36 meters 95% considering only a signal in space errors and using an all-in-view receiver algorithm [SPSPS Section 3.4],
e. the vertical positioning domain accuracy for the worst site in the service volume measured over a 24-hour interval is less than or equal to 77 meters 95% considering only a signal in space errors and using an all-in-view receiver algorithm [SPSPS Section 3.4], and
f. the time transfer accuracy is less than or equal to 40 nsec 95%, averaged over the service volume over any 24-hour period assuming an all-in-view receiver at a surveyed location and considering only the SIS component of accuracy [SPSPS Section 3.4].

### 3.1.5 Verification of GPS Status and Problem Reporting Standard

The notices described below and their verification are the responsibility of the SPS provider and are provided to the USCG Navigation Information Service (NIS) and the FAA Notice to Airmen (NOTAM) systems. Civil monitoring shall:

a. verify that notice is issued no less than 48 hours in advance of any planned disruption of the SPS (defined to be periods in which the GPS is not capable of providing SPS as specified in the SPS Performance Standard) as specified in the SPSPS [SPSPS Section 3.5],

b. verify that notice is issued no less than 48 hours in advance of scheduled change in constellation operational status that affects the service being provided to GPS users [SPSPS Section 3.5],
c. detect errors in Notice Advisory to Navstar Users (NANU) messages. Examples of errors to be found include inconsistent times and inconsistent relationship between NAVSTAR ID and PRN ID [SPSPS Section 3.5], and
d. monitor the time to issue a notification of unscheduled outages or problems [SPSPS Section 3.5].

## 3.2 CIVIL SIGNAL MONITORING REQUIREMENTS

### 3.2.1 Verification of Signal

Civil signal monitoring shall verify that:

a. the broadcast of the GPS ranging signal on L1 C/A is a signal centered about 1575.42 MHz [IS-GPS-200 Section 3.3.1.1],
b. the broadcast of the GPS ranging signal on L2C is a signal centered about 1227.60 MHz [IS-GPS-200 Section 3.3.1.1], and
c. the broadcast of the GPS ranging signal on L5 is a signal centered about 1176.45 MHz [IS-GPS-705 Section 3.3.1.1].

### 3.2.2 Verification of Civil Ranging Codes

Civil signal monitoring shall:

a. detect instances of non-standard code transmission of the L1 C/A code [IS-GPS-200 Section 3.2.1],
b. detect instances of non-standard code transmission of the L2 civil-moderate (CM) and L2 civil-long (CL) code [IS-GPS-200 Section 3.2.1],
c. track the C/A code on L1 regardless of health status[1] [IS-GPS-200 Section 3.2.1.3],
d. track the CM-code on L2 regardless of health status [IS-GPS-200 Section 3.2.1.4],
e. track the CL-code on L2 regardless of health status [IS-GPS-200 Section 3.2.1.5],
f. detect when any satellite transmits pseudorandom noise (PRN) codes 33 through 37[IS-GPS-200 Table 3-1 and Table 3-1A],
g. detect when the average time difference between the L1 C/A code and L1 P(Y) code transitions exceeds 10 nsec (two sigma) [IS-GPS-200 Section 3.2.1.3 and Section 3.3.1.8],
h. detect when the L1 C/A navigation message is not synchronized to L1 P(Y) X1 epochs [IS-GPS-200 Section 3.3.4.Fig 3-16],
i. detect instances of non-standard code transmission of the L5 I5 code [IS-GPS-705 Section 3.2.1.2],
j. detect instances of non-standard code transmission of the L5 Q5 code [IS-GPS-705 Section 3.2.1.2],

[1] In the case of requirements c, d, e, k, and l, the term "track" means to acquire the signal, collect measurements, and collect the navigation message data (if available). In these cases, the ICD reference in the square bracket denotes the section of the ICD where the relevant signal is described and is not an indication of traceability.

k. track the I5-code on L5 regardless of health status [IS-GPS-705 Section 3.2.1],
l. track the Q5-code on L5 regardless of health status [IS-GPS-705 Section 3.2.1],
m. detect when the L2C navigation message is not synchronized to L1 P(Y) X1 epochs [IS-GPS-200 Section 3.3.3.1.1], and
n. detect when the L5 navigation message is not synchronized to L1 P(Y) X1 epochs [IS-GPS-705 Section 3.3.3.1.1].

### 3.2.3 Verification of Civil Signal Power Level

Civil signal monitoring shall:

a. verify the received minimum radio frequency (RF) signal strength on L1 C/A is at or above -158.5 dBW for each space vehicle (SV) [IS-GPS-200 Section 3.3.1.6],
b. verify the received minimum RF signal strength on L2C is at or above -160.0 dBW for each SV transmitting the L2C signal. [IS-GPS-200 Section 3.3.1.6],
c. verify the received minimum RF signal strength on L5/I5 is at or above -157.9 dBW for each SV transmitting the L5 signal. [IS-GPS-705 Section 3.3.1.6], and
d. verify the received minimum RF signal strength on L5/Q5 is at or above -157.9 dBW for each SV transmitting the L5 signal. [IS-GPS-705 Section 3.3.1.6].

### 3.2.4 Verification of Navigation Message

The following requirements address the correctness of the navigation message data with respect to the definitions contained in the relevant interface documents. Where the term “correctly set” is used, it may be interpreted to mean either “matching the intent of the operators” or “consistent with sanity checks” or some combination of both. There is no intent to imply that civil signal monitoring must perform an independent solution for each SV and compare the results to the broadcast navigation message.

Civil signal monitoring shall:

a. verify the GPS time scale is within one microsecond of the Coordinated Universal Time (UTC) modulo one second [IS-GPS-200 Section 3.3.4, IS-GPS-705 Section 3.3.4],
b. detect the transmission of alternating ones and zeroes in words 3 through 10 in place of normal L1 C/A navigation message (NAV) data [IS-GPS-200 Section 20.3.2],
c. verify the correct time of week count is present in the handover word (HOW) [IS-GPS-200 Section 20.3.3.2, 30.3.3; IS-GPS-705 20.3.3],
d. verify the GPS week number increments at each end/start of week epoch [IS-GPS-200 Section 20.3.3.3.1.1],
e. verify that the clock parameters in subframe 1 are correctly set [IS-GPS-200 Section 20.3.3.3.1],
f. verify that the ephemeris in subframes 2 and 3 is correctly set [IS-GPS-200 Section 20.3.3.4.1],
g. verify that the time of ephemeris ($t_{oe}$) value, for at least the first data set transmitted by an SV after an upload, is different from that transmitted prior to the cutover as specified in IS-GPS-200 [IS-GPS-200 Section 20.3.3.4.1, 20.3.4.5],

h. verify that each SV is in "normal operations" mode by verifying the fit interval flag is set to zero (0) and the value of the 8 lsbs of the IODC are in the range 0-239 [IS-GPS-200 Section 20.3.3.4.3.1, 20.3.4.4],
i. verify that the almanac message for any dummy SVs contains alternating ones and zeros with valid parity [IS-GPS-200 Section 20.3.3.5.1.2],
j. verify that the almanac parameters provided via L1 C/A navigation message are updated by the Control Segment at least once every 6 days as specified in IS-GPS-200 [IS-GPS-200 Section 20.3.3.5.1.2],
k. verify that the almanac parameters provided via L2C and L5 navigation message are updated by the Control Segment at least once every 3 days as specified in IS-GPS-200 [IS-GPS-200 Section 30.3.3.4.6.1; IS-GPS-705 Section 20.3.3.4.6.1],
l. verify that the almanac reference week and time of almanac ($t_{oa}$) define a time that is between the time of transmission and a time no more than 3.5 days in the future from the time of transmission [IS-GPS-200 Section 20.3.3.5.1.5, 20.3.3.5.2.2, 30.3.3.4.1; IS-GPS-705 Section 20.3.3.4.1],
m. verify that UTC parameters are correctly set as specified in IS-GPS-200 and IS-GPS-705 [IS-GPS-200 Section 20.3.3.5.1.6, 20.3.3.5.2.4, 30.3.3.6; IS-GPS-705 Section 20.3.3.6],
n. verify that the UTC parameters provided via L1 C/A navigation message are updated by the Control Segment at least once every 6 days [IS-GPS-200 Section 20.3.3.5.1.6],
o. verify that the UTC parameters provided via the L2C and L5 navigation messages are updated by the Control Segment at least once every 3 days [IS-GPS-200 Section 30.3.3.6; IS-GPS-705 Section 20.3.3.6],
p. verify that the single frequency ionospheric parameters are correctly set as specified in IS-GPS-200 [IS-GPS-200 Section 20.3.3.5.1.7, 30.3.3.3; IS-GPS-705, Section 20.3.3.3],
q. verify that the single frequency ionospheric data are updated by the Control Segment at least once every 6 days [IS-GPS-200 Section 20.3.3.5.1.7, 30.3.3.3.1.1.2; IS-GPS-705, Section 20.3.3.3.1.3],
r. verify that the almanac is correctly set [IS-GPS-200 Section 20.3.3.5.2.1, 30.3.3.4.5, 30.3.3.4.6; IS-GPS-705 Section 20.3.3.4.5, 20.3.3.4.6],
s. verify that the almanac time parameters can be used to compute GPS time within the threshold specified in IS-GPS-200 [IS-GPS-200 Section 20.3.3.5.2.2],
t. verify that the almanac time parameters provided a statistical URE component that is less than 135 m one sigma [IS-GPS-200 Section 20.3.3.5.2.3],
u. verify that the absolute value of the difference between the untruncated week number (WN) and truncated leap second week number (WNt) values does not exceed 127 when $\Delta t_{LS}$ and $\Delta t_{LSF}$ differ [IS-GPS-200 Section 20.3.3.5.2.4],
v. verify that the reference time for UTC is correctly set [IS-GPS-200 Section 20.3.3.5.2.4],
w. verify that the transmitted issue of data clock (IODC) is different from any value transmitted by the SV during the time period specified in IS-GPS-200 [IS-GPS-200 Section 20.3.4.4],
x. verify that the transmitted issue of data ephemeris (IODE) is different from any value transmitted by the SV during the time period specified in IS-GPS-200 [IS-GPS-200 Section 20.3.4.4],
y. verify that the transmitted IODC values obey the assignment rules specified in IS-GPS-200 (assuming normal operations are in effect) [IS-GPS-200 Section 20.3.4.4, Table 20-XI, 20-XII],
z. detect default message data [IS-GPS-200 Section 30.3.2, 30.3.3],

aa. verify that the group delay differential terms in L2C Message Type 30 are set correctly [IS-GPS-200 Section 30.3.3.3.1.1],
bb. verify that the reduced almanac parameters are updated by the Control Segment at least once every 3 days [IS-GPS-200 Section 30.3.3.4.6.1],
cc. verify that the week number of transmission in the L1 C/A navigation message is correctly set [IS-GPS-200 Section 20.3.3.3.1.1],
dd. verify that the L1 C/A subframe 1 week number and the L2C NAV Message Type 10 transmission week number are consistent [IS-GPS-200 Section 20.3.3.3.1.1, 30.3.3.1.1.1],
ee. verify that the group delay differential terms in L5 messages are set correctly [IS-GPS-705 Section 3.3.1.7.1, 3.3.1.7.2, 20.3.3.3],
ff. verify that the L1 C/A subframe 1 week number and the L5 Message Type 10 transmission week number are consistent [IS-GPS-200 Section 20.3.3.3.1.1, IS-GPS-705 Section 20.3.3.1.1.1], and
gg. verify that the almanac reference week in the L5 navigation message is correctly set [IS-GPS-705 Section 20.3.3.4.1.5].

### 3.2.5 Verification of Signal Behaviors

Civil signal monitoring shall:

a. detect deformations in the L1 carrier and L1 C/A signal[2],
b. detect deformations in the L2 carrier and L2C signal, and
c. detect deformations in the L5 carrier and L5 signal.

## 3.3 REPORTING AND NOTIFICATION REQUIREMENTS

a. All events shall be reported to the satellite operators as part of their normal operational duties[3]. To the extent practical, reports shall include the measured or calculated values, the threshold values that are exceeded, and shall identify the source of the data.
b. Civil monitoring shall provide electronic notification of events to agencies identified to receive notification through published documents and memorandums of agreement (currently U.S. Coast Guard and the Federal Aviation Administration) for further distribution to user groups as required and with a timeliness to which each side has agreed[4].
c. Civil monitoring shall detect events in the times specified in Table 3.3-1[5].

[2] In this context, the term "deformations" includes code/carrier divergence. While there are no documented U.S. Government commitments regarding these anomalies, they form the basis of certification for key civilian GPS augmentations, such as the Local Area Augmentation System (LAAS). A detailed description of signal deformation is provided in FAA specification FAA-E-2937A "Category I Local Area Augmentation System Ground Facility") April 17 2002), Section 3.1.2.1.1a and Appendix E.
[3] Civil monitoring and responses to reported civil service and civil signal events need to be incorporated into the service provider's standard operating procedures in order to assure a timely response to events.
[4] Existing memoranda of agreement between DoD and DOT call for notification from the service provider to these civil organizations. See "Civil Use of the GPS" Section 5, paragraph b; Annex 3, Section 5, paragraph d, and Annex 3, Section 6, paragraph b. The new part of this requirement is that it be performed electronically.
[5] The values in Table 3-4.2 were selected to be commensurate with the type of the event and the monitoring interval.

**Table 3.3-1 Event Detection Times**

| Event Title | Detection Time |
|---|---|
| Constellation management events (Section 3.1.1) | Within 24 hours of onset of event |
| Service availability events (Section 3.1.2) | Within 24 hours following onset of event |
| Service reliability events (Section 3.1.3) | Occurrence of hazardously misleading information event within 24 hours; all others within 30 days following data collection period |
| GPS accuracy events (Section 3.1.4) | Within 1 day following data collection period |
| GPS status and problem reporting events (Section 3.1.5) | Within 1 day following transmission of erroneous status and problem report |
| Signal events (Section 3.2.1) | Within 1 minute of onset of event |
| Civil ranging code events (Section 3.2.2) | Within 1 minute of onset of event |
| Signal power level events (Section 3.2.3) | Within 90 days of onset of event |
| Navigation message events (Section 3.2.4) | Within 1 minute following transmission |
| Signal behavior events (Section 3.2.5) | Within 90 days of onset of event |

d. Civil monitoring shall report current GPS availability and accuracy levels to the service provider and to civil interface agencies[6].
e. Any limitations or failures in civil monitoring that could restrict the ability to fulfill the requirements defined in 3.1 or 3.2 shall be reported.

### 3.4 ANALYSIS AND DATA ARCHIVING REQUIREMENTS

This section summarizes the data analysis and data archiving requirements necessary to support civil monitoring. In order to support civil monitoring, the organization performance civil monitoring shall:

a. retain copies of all raw sensor data for a period not less than seven years[7],
b. retain copies of all reports issued as a result of civil monitoring without limit[8],
c. perform statistical analysis on raw sensor data of all system performance monitoring requirements identified in Section 3.1,
d. perform the analysis necessary to assess current signal-in-space positioning service as identified in Section 3.1 [SPSPS Section 3.4],
e. perform the analysis necessary to assess current signal-in-space time transfer service as identified in Section 3.1 [SPSPS Section 3.4],
f. perform the analysis necessary to assess current signal-in-space range error, range rate error, and range acceleration performance as identified in Sections 3.1 and 3.2 [SPSPS Section 3.4],

[6] This requirement ensures that the civil interface organizations will have information on the current performance of GPS, even when it is meeting or exceeding required performance.
[7] This requirement is intended to ensure sufficient time for the U.S. Government to resolve legal and international issues related to service provision. Data to be retained includes, but is not limited to, raw sensor observations, navigation message data, and all derivative products.
[8] This requirement will ensure adequate record keeping for a government-provided service.

g. retain the results of the analyses performed as a result of requirements c, d, e, and f for a period not less than seven years[9],
h. assess the time to issue a NANU prior to a scheduled event as identified in Section 3.2 [SPSPS Section 3.5], and
i. assess the time to issue a NANU following an unscheduled event as identified in Section 3.2 [SPSPS Section 3.5].

### 3.5 INFRASTRUCTURE REQUIREMENTS

This section describes the requirements levied on the infrastructure to ensure the availability and usability of civil monitoring data. The civil monitoring capability shall:

a. detect and reject raw measurement data that has been tampered with, and shall notify operators of such instances[10] [USAF officials, including AFSPC/DRN, 14AF, and 2SOPS], and
b. collect the necessary observations to perform the analyses in Section from all SVs continuously and with sufficient redundancy to support unambiguous isolation of errors[11].

### 3.6 OPERATIONS INTEGRATION REQUIREMENTS

a. Civil monitoring shall be fully incorporated into satellite operations, including daily operation and standards and evaluation processes[12].

[9] This requirement supports trending of GPS civil performance metrics and provides information on system performance even when it is operating within specification.
[10] This requirement protects the integrity of the monitoring results by assuring the integrity of the source data. Exceptions to this requirement may be considered during system architecture definition and system design if such exceptions address tamper detection and strengthen the overall integrity of the system.
[11] This requirement is derived from the detection time requirements stated in Table 3.3-1. In order to detect specified signal and navigation message events within a minute, it is necessary to have continuous observations. In order to have confidence in the detection, redundant observations from multiple sites are necessary.
[12] Experience has demonstrated that activities not incorporated into the day-to-day process of the satellite operators are not fully implemented and may be lost or ignored.

# 4 PARTITIONING OF REQUIREMENTS

Table 4-1 presents a partitioning of the requirements between those that are judged to be unique to the civil community and those that are believed to be more general in nature. Only the requirements in Sections 3.1 and 3.2 are covered in Table 4-1. Requirements in the remaining sub-sections of Section 3 are requirements associated with the monitoring system itself and are applicable in either case.

Table 4-1 – Partitioning of Requirements

| Section | Civil Unique | General |
|---|---|---|
| 3.1 | - | - |
| 3.1.1 | - | - |
| 3.1.1.a | | X |
| 3.1.1.b | | X |
| 3.1.1.c | | X |
| 3.1.1.d | | X |
| 3.1.2 | - | - |
| 3.1.2.a | | X |
| 3.1.2.b | | X |
| 3.1.2.c | X | |
| 3.1.2.d | X | |
| 3.1.2.e | X | |
| 3.1.2.f | X | |
| 3.1.3 | - | - |
| 3.1.3.a | X | |
| 3.1.3.b | X | |
| 3.1.3.c | | X |
| 3.1.4 | - | - |
| 3.1.4.a | X | |
| 3.1.4.b | X | |
| 3.1.4.c | X | |
| 3.1.4.d | X | |
| 3.1.4.e | X | |
| 3.1.4.f | X | |
| 3.1.5 | - | - |
| 3.1.5.a | X | |
| 3.1.5.b | X | |
| 3.1.5.c | X | |
| 3.1.5.d | X | |
| 3.2 | - | - |
| 3.2.1 | - | - |
| 3.2.1.a | | X |
| 3.2.1.b | | X |
| 3.2.1.c | | X |

| | | |
|---|---|---|
| 3.2.2 | - | - |
| 3.2.2.a | | X |
| 3.2.2.b | X | |
| 3.2.2.c | | X |
| 3.2.2.d | X | |
| 3.2.2.e | X | |
| 3.2.2.f | | X |
| 3.2.2.g | | X |
| 3.2.2.h | | X |
| 3.2.2.I | | X |
| 3.2.2.j | | X |
| 3.2.2.k | | X |
| 3.2.2.l | | X |
| 3.2.2.m | X | |
| 3.2.2.n | | X |
| 3.2.3 | - | - |
| 3.2.3.a | | X |
| 3.2.3.b | | X |
| 3.2.3.c | | X |
| 3.2.3.d | | X |
| 3.2.4 | - | - |
| 3.2.4.a-z | | X |
| 3.2.4.aa-dd | X | |
| 3.2.4.ee-gg | | X |
| 3.2.5 | - | - |
| 3.2.5.a | | X |
| 3.2.5.b | | X |
| 3.2.5.c | | X |

# 5 NOTES

## 5.1 ADDITIONAL REFERENCES

The following documents and articles provide useful reference information in addition to those documents listed in Section 2.

1. *Department of Defense World Geodetic System 1984, Its Definition and Relationships with Local Geodetic Systems*, DMA Publication TR-8350.2 (unlimited distribution), Second Edition, September 1, 1991.
2. Clyde R. Greenwalt and Melvin E. Shultz, *Principles of Error Theory and Cartographic Applications*, United States Air Force Aeronautical Chart and Information Center Publication ACIC Technical Report No. 96 (unlimited distribution), February 1962.
3. Gerald J. Hahn and William Q. Meeker, *Statistical Intervals: A Guide For Practitioners* (New York: John Wiley & Sons, Inc., a Wiley-Interscience Publication, 1991).

## 5.2 CIVIL GPS MONITORING SERVICE USE CASES

The following use cases illustrate the anticipated applications of civil monitoring.

### 5.2.1 GPS Operational Command and Control

This use case describes how civil monitoring is used to support GPS mission operations and ensure highest availability of service.

| | |
|---|---|
| Entry Criteria: | • GPS is operational |
| Actors: | • Satellite Operators (2SOPS currently)<br>• Supporting monitoring facilities/operators<br>• GPS operational control segment and space segment |
| Description: | • Civil GPS service is monitored<br>• Service anomaly is detected<br>• Satellite Operators are notified<br>• Satellite Operators take action to remedy service anomaly |
| Exit Criteria: | • Service anomaly detected within time specified<br>• Service anomaly remedied by satellite operators |
| Requirements Verified | • Requirement 3.3a |

### 5.2.2 GPS Service Standard Adherence

This use case describes how civil monitoring is used to verify U.S. Government commitments to GPS users.

| | |
|---|---|
| Entry Criteria: | • GPS is operational |
| Actors: | • Satellite Operators (2SOPS currently)<br>• Supporting monitoring facilities/operators<br>• GPS operational control segment and space segment |
| Description: | • Civil GPS service is monitored<br>• Service anomaly is detected<br>• Satellite Operators are notified<br>• Appropriate civil agencies are notified (Section 3.3b)<br>• Satellite Operators take action to remedy service standard failure |
| Exit Criteria: | • Service anomaly detected and resolved within time specified |
| Requirements Verified | • Sections 3.1.1, 3.1.2, 3.1.3, 3.1.4, 3.1.5, 3.3b |

### 5.2.3 GPS Signal Specification Compliance

This use case describes how civil monitoring is used to verify the compliance of the GPS signal with U.S. Government specifications.

| | |
|---|---|
| Entry Criteria: | • GPS is operational |
| Actors: | • Satellite Operators (2SOPS currently)<br>• Supporting monitoring facilities/operators<br>• GPS operational control segment and space segment |
| Description: | • Civil GPS service is monitored<br>• Service anomaly is detected<br>• Satellite Operators are notified<br>• Satellite Operators take action to remedy signal specification failure |
| Exit Criteria: | • Service anomaly detected and resolved within time specified |
| Requirements Verified | • Sections 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.3a |

### 5.2.4 Situational Awareness

This use case describes how civil monitoring is used to provide user interface organizations with a real-time and predicted situational awareness of GPS service.

| | |
|---|---|
| Entry Criteria: | • GPS is operational |

| | |
|---|---|
| Actors: | • GPS operational control segment and space segment |
| Description: | • Civil GPS service is monitored<br>• Civil monitor reports status of constellation to appropriate agencies (Section 3.3d) |
| Exit Criteria: | • Reports are created and distributed |
| Requirements Verified | • Sections 3.3 and 3.4 |

### 5.2.5 Past Assessment

This use case describes how civil monitoring is used to assess past service at any time in any part of the world. Such a capability would be useful in resolving liability claims or misinformation regarding GPS performance.

| | |
|---|---|
| Entry Criteria: | • GPS is operational |
| Actors: | • GPS operational control segment and space segment |
| Description: | • Civil GPS service is monitored<br>• Civil monitor records performance of civil GPS service<br>• Civil monitor generates reports and analyses for past periods as requested by service provided and/or civil interface agencies |
| Exit Criteria: | • Reports are created and distributed |
| Requirements Verified | • Section 3.3 and 3.4 |

## 5.3 DEFINITIONS

The following definitions apply to the terms and acronyms used in this specification.

| | |
|---|---|
| Accuracy | The degree of conformance between the estimate or measured position and/or velocity of a platform at a given time and its true position or velocity [Federal Radionavigation Plan (FRP), Appendix A] |
| Availability | The percentage of time that the services of a system are usable. Availability is an indication of the ability of the system to provide usable service within the specified coverage area. Signal availability is the percentage of time that navigation signals transmitted from external source are available for use. PDOP availability is the percentage of time over a specified time interval that the PDOP is less than or equal to a specified value [FRP, Appendix A] |

| | |
|---|---|
| Continuity | The ability of the total system to perform its function without interruption during the intended operation. The probability that the specified system performance will be maintained for the duration of a phase of operation, presuming that the system was available at the beginning of that phase of operation [FRP] |
| Coverage | The surface area or space volume in which the signals are adequate to permit the user to determine position to a specified level of accuracy [FRP] |
| Hazardously Misleading Information Event | An event that occurs when the Signal in Space User Range Error is greater than 30 meters while the satellite is set healthy by the User Range Accuracy multiplied out to 4.42 standard deviations is less than 30 meters [SPSPS, Section 3.4, Appendix A] |
| Healthy | Satellite signal status as set in word 3 of the transmitting satellite [IS-GPS-200 Section 20.3.3.3.1.4] |
| Integrity | Integrity is a measure of the trust which can be placed in the correctness of the information supplied by the signal-in-space. Integrity includes the ability of the space and control segment to provide timely alerts or warnings (including switches to non-standard code) to users when the signal-in-space error may exceed the accuracy broadcast to the user [FRP][13] |
| Position Dilution of Precision | A scalar measure representing the contribution of the GPS satellite configuration geometry to the accuracy in three dimensional position [FRP, Appendix A] |
| Reliability | The probability of performing a specified function without failure under given conditions for a specified period of time [FRP, Appendix A] |
| Service volume | The spatial volume supported by SPS performance standards. Specifically, the SPS Performance Standard supports the terrestrial service volume. The terrestrial service volume covers from the surface of the Earth up to an altitude of 3,000 kilometers [SPSPS, Appendix A,] |
| Signal availability | The percentage of time that navigation signals transmitted from an external source are available for use |
| Spherical error probable | The radius of a sphere with which there is a 50 percent probability of locating a point or being located [FRP] |

[13] This definition is from the Draft 2005 FRP.

| | |
|---|---|
| Standard Positioning Service | A positioning and timing service provided on the GPS L1 signal. The L1 signal, transmitted by all GPS satellites, contains a Coarse / Acquisition (C/A) code and a navigation data message. The L-band SPS ranging signal is a 2.046 MHz null-to-null bandwidth signal centered about L1. The transmitted ranging signal that comprise the GPS-SPS is not limited to the null-to-null signal and extends through the band 1563.42 to 1587.42 MHz [SPSPS, Section 1, Appendix A] |
| User range error | The instantaneous difference between a ranging signal measurement (neglecting user clock bias), and the true range between the satellite and a GPS user at any point within the service volume [FRP, Appendix A] |

## 5.4 ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| 14AF | 14th Air Force |
| 2SOPS | 2nd Space Operations Squadron |
| AFSPC | Air Force Space Command |
| C/A | Course/Acquisition code |
| CL | Civil-long |
| CM | Civil-moderate |
| CMPS | Civil Monitoring Performance Specification |
| DoD | Department of Defense |
| DOT | Department of Transportation |
| DRN | Requirements Directorate, Space-based Communication & Navigation Division |
| FAA | Federal Aviation Administration |
| FRP | Federal Radionavigation Plan |
| GPS | Global Positioning System |
| HMI | Hazardously misleading information |
| HOW | Handover word |
| ICD | Interface Control Document |
| IODC | Issue of data clock |
| IODE | Issue of data ephemeris |
| ITS | Intelligent Transportation System |
| LAAS | Local Area Augmentation System |
| JPO | GPS Joint Program Office |

| | |
|---|---|
| MS | Monitor Station |
| NANU | Notice: Advisory to Navstar Users |
| NAV | Navigation message |
| NIS | Navigation Information Service |
| NOTAM | Notice to Airmen |
| PDOP | Position dilution of precision |
| PPS | Precise Positioning Service |
| PRN | Pseudorandom noise |
| PRN ID | PRN Identifier |
| RF | Radio frequency |
| SIS | Signal in space |
| SPS | Standard Positioning Service |
| SPSPS | SPS Performance Standard |
| SV | Space vehicle |
| TLM | Telemetry word |
| URA | User range accuracy |
| URE | User range error |
| USC | United States code |
| UTC | Coordinated Universal Time |
| WN | Week number |
| WNt | Week number associated with leap second |