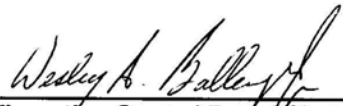


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Date: 10 April 2003

Military Standard Order

Subject: 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

- 1. PURPOSE.** This Military Standard Order (MSO) prescribes the minimum performance standards that airborne area navigation sensors using the Global Positioning System (GPS) / Precise Positioning Service (PPS) must meet to be identified with the applicable MSO marking. The similarity of this MSO with Technical Standard Order (TSO) C-145, "Airborne Navigation Sensors using the Global Positioning System (GPS) augmented by the Wide Area Augmentation System (WAAS)", is intentional.
- 2. APPLICABILITY.** The standards of this MSO apply to equipment intended to provide position information to a navigation management unit that provides appropriate flight path, planning, outputs supporting guidance commands enabling pilot flight path tracking, navigation status/progress, and positional/situational awareness. These capabilities are essential to the conduct of operations in Required Navigation Performance (RNP) airspace. These standards do not address integration issues with other avionics, such as the potential for the sensor to inadvertently command an autopilot hardover or the suitability of the sensor for use in a multi-sensor navigation suite. These standards also do not address the use of position information for other applications such as automatic dependent surveillance.
- 3. SUBSTITUTION.** Airborne navigation sensors identified with the MSO-C145 marking can substitute for airborne navigation sensors identified with a TSO-C145 marking in RNP-20 through RNP-0.3 area navigation (RNAV) operations, but are not acceptable substitutes in precision approach operations. (The precision approach functions required of TSO-C145 marked airborne navigation sensors for vertical navigation are not required of MSO-C145 marked airborne navigation sensors.) Airborne navigation sensors identified with the MSO-C145 marking are also acceptable substitutes for airborne navigation sensors identified with a TSO-C129 Class B() or TSO-C129a Class B() marking in RNP-20 through RNP-0.3 RNAV operations.

NOTE: Airborne navigation sensors identified with the MSO-C145 marking are required to provide vertical navigation (VNAV) performance only to the extent specified in Section 4 below. The specified level of VNAV performance is not intended to support VNAV or precision approach operations in RNP airspace. It is expected that these operations will be conducted using barometric altimetry.

4. REQUIREMENTS. Airborne navigation sensors using PPS that are to be so identified must meet the minimum performance standards for Class Beta-1 and Class Beta-2 equipment set forth in Section 2 of RTCA/DO-229B, “Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Equipment”, dated 6 October 1999 except as specified herein. MSO-C145 marked airborne navigation sensors are not required to meet the minimum performance standards for Class Beta-3 equipment. Class Beta-1, Class Beta-2, and Class Beta-3 equipment are defined in Section 1 of RTCA/DO-229B.

a. Failure Condition Classification. Failure of the function defined in paragraph 2 of this MSO has been determined to be a major failure condition for loss of function and malfunction of en route, terminal, or non-precision approach position data. The applicant must develop the system to at least the design assurance level commensurate with this hazard classification.

b. Exceptions to RTCA/DO-229B.

(1) Precedence. In the event of a conflict between the performance requirements or conditions imposed by the prime item specification for the GPS/PPS navigation sensor and the performance requirements or conditions imposed by this MSO through the invocation of RTCA/DO-229B, the precedence of the performance requirements or conditions shall be as follows. If the performance requirements or conditions imposed by the prime item specification are more rigorous or stringent than the requirements or conditions imposed by this MSO, then the performance requirements or conditions imposed by the prime item specification shall take precedence, unless otherwise explicitly specified in this MSO. However, if the prime item specification requirements or conditions do take precedence, those performance requirements or conditions do not necessarily need to be met in order to be identified with the applicable MSO marking (see paragraph 6a.(e)(13)).

(2) Equipment Performance and Test Procedure Deletions. The following paragraphs and Sections of RTCA/DO-229B are not required for equipment certified to Class Beta-1 or to Class Beta-2 requirements: 2.1.1.3, 2.1.1.4, 2.1.1.5.2 through 2.1.1.5.4, 2.1.1.8.2, 2.1.2.2.2.1, 2.1.3.2.2.1, 2.1.3.7 through 2.1.3.9, 2.1.4, 2.2, 2.3, 2.5.2, 2.5.9.3.3.1, 2.5.10, and 2.5.11.

(3) Installed Equipment Performance Deletions. The following paragraphs and Sections of RTCA/DO-229B will not be required for installations of equipment certified to Class Beta-1 or to Class Beta-2 requirements: 3.3 and 3.4.

(4) Normative Appendix Deletions. The following normative appendices of RTCA/DO-229B are not required for equipment certified to Class Beta-1 or to Class Beta-2 requirements: Appendix A except for Section A.4.2.4, Appendix D, Appendix F, Appendix H, Appendix J, Appendix P, and Appendix Q. It is noted that paragraph 1.1 of RTCA/DO-229B defines Appendices M through O as being informative rather than normative.

(5) GPS/PPS vice GPS/WAAS. Substitute "GPS/PPS" for all references to "GPS/WAAS" and/or "WAAS" in RTCA/DO-229B since the ability to use WAAS signals is not required (e.g., Substitute "GPS/PPS positioning" for "GPS/WAAS positioning", "GPS/PPS navigation" for "GPS/WAAS navigation", etcetera).

(6) PPS-Based vice WAAS-Based. Substitute "PPS-based" for all references to "WAAS-based" in RTCA/DO-229B since the ability to use WAAS signals is not required.

(7) WAAS Satellites, WAAS Signals, Etcetera. Delete all references to WAAS satellites, WAAS signals, WAAS data, WAAS corrections, WAAS information, WAAS coverage area, etcetera in RTCA/DO-229B since the ability to use WAAS signals is not required.

(8) HPL_{WAAS} and VPL_{WAAS}. Delete all references to the Horizontal Protection Level computed using WAAS (HPL_{WAAS}) and the Vertical Protection Level computed using WAAS (VPL_{WAAS}) in RTCA/DO-229B since the ability to use WAAS signals is not required.

(9) PPS Simulator vice GPS/WAAS Simulator. Substitute "GPS/PPS signal generator (simulator)" for all references to "GPS/WAAS signal generator (simulator)" in RTCA/DO-229B since the ability to use WAAS signals is not required.

(10) Precision Approach. Delete all references to precision approach, specifically including but not limited to Category I precision approach in RTCA/DO-229B since the ability to support precision approach is not required for equipment certified to Class Beta-1 or Class Beta-2 requirements.

(11) Primary (Sole) Means. Substitute "primary means" for all references to "primary (sole) means" in RTCA/DO-229B since sole means is not an objective for PPS.

(12) SPS Signal Specification References. Substitute a reference to ICD-GPS-200 (i.e., "Ref. ICD-GPS-200") in lieu of all references to specific paragraphs of the main body of the SPS Signal Specification in RTCA/DO-229B since ICD-GPS-200 is the governing document for GPS signal-in-space technical details.

(13) System Overview. In lieu of the information in paragraph 1.2 of RTCA/DO-229B, substitute the following information:

"GPS provides two defined levels of positioning service: (1) the Precise Positioning Service (PPS), and (2) the Standard Positioning Service (SPS). When employed as described herein, the PPS is sufficient to serve as the basis for Area Navigation (RNAV) in Required Navigation Performance (RNP) airspace for RNP-20 through RNP-0.3 RNAV operations. In the event that the PPS cannot be accessed, either because the GPS/PPS equipment lacks the requisite cryptographic keys ("PPS keys") or because of an operator-commanded PPS lock out (see Section 2.1.1.2), the SPS

is used as the basis for RNAV in RNP airspace for RNP-20 through RNP-0.3 RNAV operations subject to local Air Traffic Control (ATC) regulation."

(14) Wide Area Augmentation System. In lieu of paragraph 1.2.1 of RTCA/DO-229B, substitute the following placeholder: "Reserved."

(15) GPS Signal Characteristics. Add the following information to paragraph 1.2.2.1 of RTCA/DO-229B:

"Another PRN code, either known as the Precise (P) code or its encrypted alternative, known only as the Y code, is generated at a rate of 10.23 MHz and modulated onto both the GPS L1 frequency and onto the GPS L2 frequency (1227.6 MHz). All GPS satellites transmit at the same L1 and L2 frequencies. The carriers are modulated with a specific C/A code and a specific P(Y) code for each GPS satellite.

"Detailed PPS information is provided in the GPS PPS Performance Standard, Edition 1.

"GPS signal-in-space technical details, for both the PPS and the SPS, are provided in ICD-GPS-200C, 10 October 1993, including IRN-200C-001, 13 October 1995, IRN-200C-002, 25 September 1997, IRN-200C-003, 11 October 1999, and IRN-200C-004, 12 April 2000."

(16) Figure 1-1. In lieu of Figure 1-1 of RTCA/DO-229B, substitute the following placeholder: "Reserved."

(17) WAAS Signal Characteristics. In lieu of paragraph 1.2.2.2 of RTCA/DO-229B, substitute the following placeholder: "Reserved."

(18) Operational Goals. In lieu of the information in paragraph 1.3 of RTCA/DO-229B, substitute the following information:

"The operational goal of GPS/PPS equipment certified to Class Beta-1 or to Class Beta-2 requirements is to be able to serve as the only radionavigation equipment required onboard the aircraft to meet RNP RNAV requirements for oceanic, remote area and domestic en route, terminal and non-precision approach phases of flight.

"Additional goals for PPS are to provide:

- a) flexibility for future enhancements;
- b) truly seamless worldwide radionavigation;
- c) positioning and time for automatic dependent surveillance;

- d) ground movement monitoring (with augmentation);
- e) growth to GPS / Joint Precision Approach and Landing System (JPALS) / Local Area Augmentation System (LAAS) for Category I, II, and III precision approach;
- f) secure and reliable navigation in the presence of interference (accidental and/or intentional); and
- g) replacement of other radionavigation systems."

(19) International Compatibility. In lieu of paragraph 1.3.3 of RTCA/DO-229B, substitute the following information:

"The operational concept for the GPS/PPS is as a truly seamless worldwide source of radionavigation. As such, there should be no need for flight crew interaction based on airspace so that the flight crew should not normally have to select any other radionavigation service for RNP-20 through RNP-0.3 RNAV operations anywhere in the world.

" It is recognized that authorities in certain nations may choose to not allow GPS/PPS-based navigation or any GPS-based navigation in airspace under their control. In airspace regions where no GPS-based navigation is allowed, GPS/PPS equipment will necessarily be superfluous. In those airspace regions where GPS-based navigation is allowed but not GPS/PPS-based navigation (i.e., GPS/SPS-based navigation only), GPS/PPS equipment can still be used provided that certified equipment is able to access and operate using only the SPS. To accommodate such national peculiarities, GPS/PPS equipment will be required to incorporate an operator-commanded lock out capability which limits the equipment to employing only the SPS signals for positioning functions. The lock out capability will provide a SPS-based receiver which meets or exceeds civil standards (e.g. TSO-C129a, FAA Notice 8110.60, EUROCONTROL 003-93. See Section 2.1.1.2 for requirements applicable to this operator-commanded PPS lock out capability.

"Although the ability to use WAAS signals is not required in MSO-C145 marked airborne navigation sensors, the ability to use WAAS signals is not prohibited in MSO-C145 marked airborne navigation sensors. The ability to use Space-Based Augmentation System (SBAS) signals, such as from WAAS satellites, may provide additional international compatibility in certain airspace where the controlling authority has chosen to require the use of particular SBAS signals for specific operations. For example, the use of European Geostationary Navigation Overlay Service (EGNOS) signals could be declared as mandatory for RNP-0.3 RNAV operations at a certain airport by the State responsible for that airport due to local signal monitoring considerations. MSO-C145 marked airborne navigation sensors are allowed to incorporate abilities to use SBAS signals as an option; however, all MSO-C145 marked airborne navigation sensors are required to meet the requirements specified herein without the use of SBAS signals. Additionally, to avoid any risk of compromising the military utility of PPS, the ability to use SBAS signals is not permitted when the equipment is operating in the keyed PPS mode or when the use of the particular SBAS

signal or signals has not been intentionally selected by the operator. See paragraph 2.1.1.2.4 for requirements applicable to this optional operator-selected "SBAS use permitted" capability."

(20) Aiding and Multiple Sensors. Replace the information relating to the use of barometric altitude for the fault detection and exclusion (FDE) algorithm in paragraph 1.5 of RTCA/DO-229B as follows.

Delete the existing text which reads:

"Although it is not required, the use of barometric altitude for the fault detection and exclusion (FDE) algorithm is highly recommended. Baro-aiding can significantly improve the system availability outside of the WAAS service volume (for the en route, terminal area, and non-precision approach phases of flight, FDE is only required when the WAAS is not providing integrity). Implementations which provide increased availability may be used and may obtain operational benefits in areas outside the WAAS service volume."

Insert new text which reads:

"The ability to use barometric altitude inputs for both the fault detection and exclusion (FDE) algorithm and the position fixing algorithm is required since baro-aiding can improve GPS/PPS-based RNP RNAV availability for en route, terminal area, and non-precision approach phases of flight when these functions cannot be provided by the satellites alone. Barometric altimeter aiding is used in the FDE algorithm to provide integrity and continuity, and in the position-fixing algorithm to maintain horizontal accuracy only when these functions cannot be provided by the satellites alone. Appendix G describes the minimum requirements and test procedures for barometric altimeter aiding. Alternative implementations which provide increased availability may be used and may obtain improved operational benefits."

(21) GPS Constellation. In paragraph 1.8.1.1, substitute a matched pair of references that reads as "GPS PPS Performance Standard, Edition 1 and the GPS SPS Performance Standard, 4 October, 2001" in lieu of the existing references to "GPS SPS Signal Specification, dated June 2, 1995".

(22) RF Interference. In lieu of paragraph 1.8.1.7 of RTCA/DO-229B, substitute the following information:

"It is assumed that this document's specification of the RF signal environment (Appendix C) in which GPS/PPS navigation sensors must operate successfully during unkeyed PPS mode operations or during PPS lock out mode operations will be consistent with the real environment experienced while operating in those modes. Furthermore, it is also assumed that the RF signal environment specified in the prime item specification for the GPS/PPS navigation sensor in which the GPS/PPS navigation sensor must operate successfully during keyed PPS mode operations will be consistent with the real environment experienced while operating in the keyed PPS mode."

(23) Time of Applicability of the WAAS Signal-in-Space. In lieu of paragraph 1.8.1.8 of RTCA/DO-229B, substitute the following placeholder: "Reserved."

(24) Change of Broadcast Ephemeris. In lieu of paragraph 1.8.1.9 of RTCA/DO-229B, substitute the following placeholder: "Reserved."

(25) WAAS Regional Message Type (Message Type 27). In lieu of paragraph 1.8.1.10 of RTCA/DO-229B, substitute the following placeholder: "Reserved."

(26) Precision Approach Applications. In lieu of Section 1.8.2 of RTCA/DO-229B, substitute the following placeholder: "Reserved."

(27) GPS Signal Processing Requirements. In lieu of the requirements in paragraph 2.1.1.2 of RTCA/DO-229B, substitute the following requirements:

"GPS/PPS equipment shall be designed to process the GPS signals and necessary data described in the GPS PPS Performance Specification under interference conditions specified in Appendix C for L1 operation, and under the minimum signal conditions defined in Section 2.1.1.10. For L2 operation the interfering CW signals are the same as for L1, but offset in frequency. The minimum signals for PPS L1 and L2 should be suitably adjusted for relative satellite signal level. GPS/PPS equipment shall also be designed to process the GPS signals and necessary data described in the GPS SPS Performance Standard under interference conditions described in Appendix C and under the minimum signal conditions defined in Section 2.1.1.10. If dual-frequency ionospheric corrections are not applied to a pseudorange, then the equipment shall decode the ionospheric coefficients in the GPS navigation message and apply the ionospheric corrections described in ICD-GPS-200. If dual-frequency ionospheric corrections are applied to a pseudorange, then the GPS ionospheric model shall not be used for that satellite. A tropospheric correction shall be applied (an acceptable algorithm is described in Appendix A, Section A.4.2.4).

"GPS satellite navigation data shall be continuously decoded while code and carrier track is maintained.

"In addition, the equipment shall not mistake one GPS satellite for another due to cross-correlation during acquisition or reacquisition. An acceptable means of preventing cross-correlation from causing a false range is to reject GPS satellite ranging data if there is a greater than 3000 km separation between satellite positions derived from the almanac and broadcast ephemerides.

"The GPS/PPS equipment shall be designed to operate in at least the following three GPS signal processing modes. GPS/PPS equipment which is unable to operate in the second mode may still be eligible for identification with the applicable MSO marking provided a deviation or waiver authorizing the omission is granted; see paragraph 6 of this MSO.

- a) Normal keyed PPS mode;

- b) Operator-commanded PPS lock out mode; and
- c) Unkeyed PPS mode."

(28) GPS Signal Processing Mode Requirements. Add the following requirements to paragraph 2.1.1.2 of RTCA/DO-229B (as modified above) to thereby produce an entirely new paragraph 2.1.1.2 with 4 subparagraphs:

"2.1.1.2.1 Normal Keyed PPS Mode

The normal GPS/PPS equipment operating mode shall be the keyed PPS mode. Whenever the equipment has been keyed with valid PPS keys, the equipment shall operate in the keyed PPS mode unless otherwise commanded by the operator. In the keyed PPS mode, all GPS related information shall be derived exclusively from the PPS signals as described in the GPS PPS Performance Standard, Edition 1, except during acquisition or reacquisition as allowed for by the prime item specification for the PPS navigation sensor.

"2.1.1.2.2 Operator-Commanded PPS Lock Out (PPS-LO) Mode

When specifically commanded by the operator (or commanded by an external system in lieu of an operator), GPS/PPS equipment operating in the keyed mode shall transition to operating in the operator-commanded PPS lock out (PPS-LO) mode. In the PPS-LO mode, all GPS related information shall be derived exclusively from the SPS signals as described in the GPS SPS Performance Standard. Commanding the PPS-LO mode differs from commanding the zeroization of the PPS keys since the PPS keys shall not be zeroized in response to the PPS-LO mode command. The PPS keys shall be retained in the PPS-LO mode and the equipment shall continue to function as a PPS receiver with all required capabilities enabled except for deriving all position related information exclusively from the SPS signals (i.e., no classified selective availability (SA) processing applied and no classified anti-spoofing (A-S) techniques employed). The use of classified SA processing and/or classified A-S techniques for functions other than deriving the output position related information is not precluded. When the PPS-LO mode is de-commanded by the operator, the equipment shall revert back to operating in the keyed PPS mode. The transitions from keyed PPS mode to PPS-LO mode, and from PPS-LO mode to keyed PPS mode, assuming that the receiver is properly keyed, shall be accomplished within 8 seconds of operator command or de-command. As an option, the PPS equipment may provide an operator-selected SBAS use permitted submode under the PPS-LO mode; see paragraph 2.1.1.2.4. GPS/PPS equipment which is unable to operate in the PPS-LO mode pursuant to a deviation or waiver (see paragraph 6 of this MSO) may incur operational restrictions that preclude access to certain airspace. GPS/PPS equipment should ignore signals other than L1 C/A in the PPS-LO mode.

"Note: If the GPS/PPS equipment can control a CRPA with switchable L1 or L2 nulling capability, the nulled frequency should focus on L1 not L2."

"2.1.1.2.3 Unkeyed PPS Mode

The back-up GPS/PPS equipment operating mode shall be the unkeyed PPS mode. Whenever the equipment has not been keyed with valid PPS keys, or the equipment has been zeroized, the equipment shall operate in the unkeyed PPS mode. As an option, the equipment may provide an operator-selected SBAS use permitted submode under the unkeyed PPS mode; see paragraph 2.1.1.2.4.

"Note: This mode is not the SPS mode. If a satellite is transmitting P-code or C/A-code on L2, the GPS/PPS equipment operating in unkeyed PPS mode should have the capability to track these codes."

"2.1.1.2.4 Operator-Selected SBAS Use Permitted (SBAS-UP) Submode

As an option, GPS/PPS equipment may provide an operator-selected SBAS Use Permitted (SBAS-UP) submode under the PPS-LO mode and/or the unkeyed PPS mode. If the GPS/PPS equipment provides an SBAS-UP submode, it shall not be accessible from the keyed PPS mode. The SBAS-UP submode, if provided, shall comply with the SBAS and WAAS related requirements specified in TSO-C145. In the event of conflict between the PPS, PPS-LO, or SPS related requirements specified herein and the SBAS and WAAS related requirements specified in TSO-C145, the requirements specified herein shall take precedence except when operating in the SBAS-UP submode."

(29) Satellite Integrity Status. In lieu of the requirements in paragraph 2.1.1.5 of RTCA/DO-229B, substitute the following requirements:

"The GPS/PPS equipment shall designate each GPS satellite as GPS UNHEALTHY or as GPS HEALTHY as defined in paragraphs 2.1.1.5.5 and 2.1.1.5.6. The latency of this designation must be consistent with the requirements of Section 2.1.1.13."

(30) GPS UNHEALTHY Designation. Replace the requirement relating to Bit 18 of the HOW in paragraph 2.1.1.5.5 of RTCA/DO-229B as follows.

Delete the existing text which reads:

"- Bit 18 of the HOW is set to 1 (Ref. 2.4.2.2 of the GPS SPS Signal Specification);"

Insert new text which reads:

"- Bit 18 of the HOW is set to 1 (Ref. ICD-GPS-200) and the equipment is operating in either the PPS-LO mode or the unkeyed PPS mode;"

(31) GPS UNHEALTHY Designation. Add the following requirement to paragraph 2.1.1.5.5 of RTCA/DO-229B:

Insert new text which reads:

"- The step detector function has declared a step error;"

(32) Satellite Selection. In lieu of the requirements in paragraph 2.1.1.6 of RTCA/DO-229B, substitute the following requirements:

"The GPS/PPS equipment shall automatically select satellites for use in the position fixing algorithm and in the FDE algorithm. As necessary to maintain an accurate position fix, maintain a reliable fault detection capability, and -- when a fault has been detected -- provide reliable fault exclusion, the minimum satellite mask angle shall be no greater than 2 degrees. If an accurate position fix cannot be maintained and/or a reliable fault detection capability cannot be maintained and/or -- when a fault has been detected -- reliable fault exclusion cannot be provided using all GPS HEALTHY satellites above the minimum satellite mask angle, then barometric altimeter aiding (if made available by aircraft to the GPS/PPS equipment) shall be used as necessary to maintain an accurate position fix, maintain a reliable fault detection capability, and -- when a fault has been detected -- provide reliable fault exclusion. See paragraph 1.5. Appendix G describes the minimum requirements and test procedures for barometric altimeter aiding.

"Note: Alternative implementations which provide increased availability may be used by the manufacturer provided they do not compromise accuracy or integrity."

(33) Sensitivity and Dynamic Range. In lieu of the requirements in paragraph 2.1.1.10 of RTCA/DO-229B, substitute the following requirements:

"The sensitivity and dynamic range of the GPS/PPS equipment shall be as specified in the prime item specification for the GPS/PPS navigation sensor. Manufacturers are encouraged, but are not required, to design the GPS/PPS equipment to be interoperable with one or more of the standard GPS/PPS antennas as specified in MSO-C144.

"Note: The receiver manufacturer should indicate in the prime item specification, the associated interface documentation, or in the installation instructions what type(s) of antenna the equipment is interoperable with and the maximum and minimum tolerable losses for installation with that type of antenna."

(34) Figure 2-2. In lieu of Figure 2-2 of RTCA/DO-229B, substitute the following placeholder: "Reserved."

(35) Protection Level. Change the title of paragraph 2.1.1.13.1 of RTCA/DO-229B to be "Protection Levels" instead of "Protection Level". In lieu of the requirements in paragraph 2.1.1.13.1 of RTCA/DO-229B, substitute the following requirements:

"Class Beta equipment shall output the Horizontal Protection Level (HPL_{FD}) as described in Sections 2.1.2.2.2 and 2.1.3.2.2). The equipment shall indicate if the HPL_{FD} cannot be calculated

(insufficient number of GPS HEALTHY satellites or inadequate geometry such that fault detection is not available).

"Notes:

- 1) *In addition to the HPL_{FD} , the equipment may output the HUL. The prime item specification may make the HUL output mandatory.*
- 2) *When no HPL_{FD} can be calculated, integrity monitoring is not provided.*

"To support potential future applications external to the equipment, Class Beta equipment shall also output the Vertical Protection Level (VPL_{FD}). The VPL_{FD} is the vertical analog of the horizontal HPL_{FD} described in Sections 2.1.2.2.2 and 2.1.3.2.2. The VPL_{FD} shall be based on the same missed alert probability, false alert probability, and failed exclusion probability requirements as the HPL_{FD} (see Sections 2.1.2.2.2 and 2.1.3.2.2). The equipment shall indicate if the VPL_{FD} cannot be calculated (insufficient number of GPS HEALTHY satellites or inadequate geometry such that fault detection is not available).

"Notes:

- 1) *In addition to the VPL_{FD} , the equipment may output the VUL. The prime item specification may make the VUL output mandatory.*
- 2) *Even if no VPL_{FD} can be calculated, integrity monitoring is still provided by Class Beta-1 or Class Beta-2 equipment so long as a valid HPL_{FD} value is calculated and output."*

(36) Accuracy. In lieu of the requirements in paragraph 2.1.2.1 of RTCA/DO-229B, substitute the following requirements:

"In the keyed PPS mode with SA in effect at any level, under the minimum signal conditions defined in Section 2.1.1.10 and interference conditions defined in Appendix C, the horizontal radial position fixing accuracy for en route (domestic and oceanic) and terminal area navigation shall not exceed 19.6 m, 2drms, when HDOP is normalized to 1.5.

"Notes:

- 1) *The assumptions are as follows: signal-in-space pseudorange accuracy of 6.0 m, 1 sigma and avionics pseudorange accuracy no worse than 2.6 m, 1 sigma (due to receiver noise at minimum signal level, multipath, etc), for a total (root-sum-square) pseudorange accuracy of 6.5 m, 1 sigma. The receiver noise accuracy at minimum signal level is assumed to be no worse than 0.40 m, 1 sigma. The multipath accuracy is assumed to be no worse than 0.70 m, 1 sigma. The dual-frequency ionospheric delay compensation (as a function of pseudorange*

measurements corrupted by receiver noise and multipath) accuracy is assumed to be no worse than 1.20 m, 1 sigma. The tropospheric delay compensation model accuracy is assumed to be no worse than 2.00 m, 1 sigma. The dynamic propagation and related accuracy is assumed to be no worse than 0.50 m, 1 sigma. Inaccuracies due to flight technical error (FTE), waypoint error, and RNAV path computation error are not included. The 2drms accuracy is approximately equal to the 95th percentile accuracy (98.2% - 95.4%).

- 2) *Section 2.5.8 describes the test for this requirement. In order to reduce the duration of testing required to demonstrate accuracy in the presence of the interference conditions, Section 2.5.8 excludes the accuracy effects of the signal-in-space pseudorange error, the multipath error, the tropospheric delay compensation model error, and the dynamic propagation and related error, and uses a dual-frequency sensor pseudorange accuracy threshold of 0.72 meters and a single-frequency sensor pseudorange accuracy threshold of 0.40 meters.*

“In the keyed PPS mode with SA in effect at any level, under the maximum signal conditions defined in Section 2.1.1.10 and interference conditions defined in Appendix C, the horizontal radial position fixing accuracy for en route (domestic and oceanic) and terminal area navigation shall not exceed 19.4 m, 2drms, when HDOP is normalized to 1.5.

“Notes:

- 1) *The assumptions are as follows: signal-in-space pseudorange accuracy of 6.0 m, 1 sigma and avionics pseudorange accuracy no worse than 2.4 m, 1 sigma (due to receiver noise at maximum signal level, multipath, etc), for a total (root-sum-square) pseudorange accuracy of 6.5 m, 1 sigma. The receiver noise accuracy at maximum signal level is assumed to be no worse than 0.15 m, 1 sigma. The multipath accuracy is assumed to be no worse than 0.70 m, 1 sigma. The dual-frequency ionospheric delay compensation (as a function of pseudorange measurements corrupted by receiver noise and multipath) accuracy is assumed to be no worse than 1.07 m, 1 sigma. The tropospheric delay compensation model accuracy is assumed to be no worse than 2.00 m, 1 sigma. The dynamic propagation and related accuracy is assumed to be no worse than 0.50 m, 1 sigma. Inaccuracies due to flight technical error (FTE), waypoint error, and RNAV path computation error are not included. The 2drms accuracy is approximately equal to the 95th percentile accuracy (98.2% - 95.4%).*
- 2) *Section 2.5.8 describes the test for this requirement. In order to reduce the duration of testing required to demonstrate accuracy in the presence of the interference conditions, Section 2.5.8 excludes the accuracy effects of the signal-in-space pseudorange error, the multipath error, the tropospheric delay compensation model error, and the dynamic propagation and related error, and*

uses a dual-frequency sensor pseudorange accuracy threshold of 0.27 meters and a single-frequency sensor pseudorange accuracy threshold of 0.15 meters.

“In the PPS-LO mode and in the unkeyed PPS mode with SA in effect at the level described in Appendix B, under the minimum signal conditions defined in Section 2.1.1.10 and interference conditions defined in Appendix C, the horizontal radial position fixing error for en route (domestic and oceanic) and terminal area navigation shall not exceed 100 m, 2drms, when HDOP is normalized to 1.5.

“Notes:

- 1) *The assumptions are as follows: signal-in-space pseudorange accuracy of 33 m, 1 sigma (due primarily to SA) and avionics pseudorange accuracy of no more than 5 m, 1 sigma (due to receiver noise at minimum signal level, multipath, etc), for a total (root-sum-square) pseudorange accuracy of 33.3 m, 1 sigma. Inaccuracies due to flight technical error (FTE), waypoint error, and RNAV path computation error are not included. The 2drms accuracy is approximately equal to the 95th percentile accuracy (98.2% - 95.4%).*
- 2) *Section 2.5.8 describes the test for this requirement. In order to reduce the duration of testing required to demonstrate accuracy in the presence of the interference conditions, Section 2.5.8 excludes the accuracy effects of the signal-in-space pseudorange error (SA and single-frequency ionospheric delay compensation model), the multipath error, the tropospheric delay compensation model error, and the dynamic propagation and related error, and uses a sensor pseudorange accuracy threshold of 5 meters.*

“If a time output is provided, it shall be within 1 second of coordinated universal time (UTC) regardless of operating mode.”

(37) FDE-Provided Integrity Monitoring. Replace the requirement relating to the URA and the associated note in paragraph 2.1.2.2.2.2 of RTCA/DO-229B as follows.

Delete the existing text which reads:

"The FDE algorithm shall use the URA broadcast to modify the thresholds for alerting. At a minimum, the FDE algorithm shall set two different thresholds: 1) an SA mode, if any satellite URA's are greater than 16 meters; 2) an SA off mode, if the URA for every satellite being used is less than or equal to 16 meters.

"Note *The URA index in the GPS SPS Signal Specification, paragraph 2.5.3 can be used to determine range-domain uncertainty by assuming the URA maps onto the near-Gaussian distribution shown in GPS SPS Signal Specification, Annex B, section 5.2.3.*"

Insert new text which reads:

"The FDE algorithm shall use the broadcast URA information (PPS or SPS, as appropriate) to modify the thresholds used for detection and alerting. The FDE algorithm shall also use estimates of the propagation path delay compensation uncertainties, multipath uncertainties, and pseudorange measurement uncertainties to modify the thresholds used for detection and alerting.

"Note The URA index (Ref. ICD-GPS-200) can be used to determine range-domain uncertainty for the signal-in-space, not including any propagation path delay compensation uncertainties, by assuming the URA maps onto a near-Gaussian distribution with a 1-sigma value in meters defined by the relationship given in ICD-GPS-200."

(38) FDE-Provided Integrity Monitoring. Replace the requirement relating to the utilization of barometric altitude in paragraph 2.1.2.2.2.2 of RTCA/DO-229B as follows.

Delete the existing text which reads:

"Equipment which utilizes barometric altitude to improve the performance of this algorithm shall meet the requirements specified in Appendix G."

Insert new text which reads:

"When the barometric altitude information is provided by the aircraft to the GPS/PPS equipment, the GPS/PPS equipment shall utilize that information to improve the performance of the FDE algorithm in compliance with the requirements specified in Appendix G. The GPS/PPS equipment shall meet the requirements specified herein regardless of whether barometric altitude information is provided by the aircraft or not."

(39) FDE-Provided Integrity Monitoring. Replace the note relating to the rationale for requiring the FDE capability in paragraph 2.1.2.2.2.2 of RTCA/DO-229B as follows.

Delete the existing text which reads:

"Note: This FDE capability is required in order to provide a transition to primary means navigation utilizing the WAAS. It enables operation outside of the WAAS coverage area and provides a secondary means of providing integrity should a catastrophic WAAS failure occur."

Insert new text which reads:

"Note: This FDE capability is required in order to provide primary means of navigation without relying on foreign or domestically operated SBAS services. It enables PPS operation regardless of SBAS coverage areas and provides global en route through non-precision approach access in support of worldwide missions where use of PPS is approved by the host nation."

(40) False Alert Probability. In lieu of the requirements in paragraph 2.1.2.2.2.3 of RTCA/DO-229B, substitute the following requirements:

"The probability of false alert shall be less than or equal to 1×10^{-5} /flight hour in the keyed PPS mode regardless of SA. The probability of false alert shall be less than or equal to 1×10^{-5} /flight hour in the PPS-LO mode or in the unkeyed PPS mode assuming that SA is operating as described in Appendix B. If these requirements are not met for a given geometry, then the detection function is defined to be unavailable for that geometry in that mode (See Section 1.7.3).

"Notes:

- 1) *The testing paragraph defines specific constellations to be used to evaluate this requirement.*
- 2) *Without SA effects, the correlation time of PPS pseudorange errors can be assumed to be 6.67 hours (See GPS PPS Performance Standard, Edition 1). If the PPS pseudorange errors correlation time were instead assumed to be 1 hour, the probability of false alert would have been 6.67×10^{-5} /flight hour. With SA effects, the correlation time of SPS pseudorange errors can be assumed to be 2 minutes."*

(41) Availability. In lieu of the requirements in paragraph 2.1.2.2.2.5 of RTCA/DO-229B, substitute the following requirements:

"The availability of the FDE algorithm to meet the above requirements with an HAL of 1 NM, when evaluated over the constellations and grids specified in the test procedures for Case 0 of Section 2.5.9 (i.e., keyed PPS mode, and SA operating as described in Appendix B), using the same satellite selection algorithm used by the equipment and a physically imposed mask angle of 2 degrees shall be greater than or equal to the following:

Availability of detection:	99.999%
Availability of exclusion:	99.900%

"The availability of the FDE algorithm to meet the above requirements with an HAL of 1 NM, when evaluated over the constellations and grids specified in the test procedures for Case 1 of Section 2.5.9 (i.e., in the PPS-LO mode or unkeyed PPS mode, and SA operating as described in Appendix B), using the same satellite selection algorithm used by the equipment and a physically imposed mask angle of 5 degrees shall be greater than or equal to the following:

Availability of detection:	99.800%
Availability of exclusion:	94.550%

"The availability of the FDE algorithm to meet the above requirements with an HAL of 1 NM, when evaluated over the constellations and grids specified in the test procedures for Case 2 of

Section 2.5.9 (i.e., in the PPS-LO mode or unkeyed PPS mode, and SA set to zero), using the same satellite selection algorithm used by the equipment and a physically imposed mask angle of 5 degrees shall be greater than or equal to the following:

Availability of detection:	99.900%
Availability of exclusion:	98.000%

"Note: These requirements are intended to provide a means to assess the adequacy of FDE algorithms. These numbers are based on simulation and analysis of the practical availability and are intended to ensure a consistent minimum capability that can be used by airspace planners and by aircraft operation directors. These availabilities have not been determined to meet all civil operational requirements."

(42) Satellite Tracking Capability. Delete the last sentence of the requirements in paragraph 2.1.2.4 of RTCA/DO-229B, and retain the first sentence, such that the requirement in paragraph 2.1.2.4 shall be as follows:

"The GPS/PPS equipment shall be capable of simultaneously tracking a minimum of 8 GPS satellites."

(43) Accuracy. In lieu of the requirements in paragraph 2.1.3.1 of RTCA/DO-229B, substitute the following requirements:

"In the keyed PPS mode with SA in effect at any level, under the minimum signal conditions defined in Section 2.1.1.10 and interference conditions defined in Appendix C, the horizontal radial position fixing accuracy for non-precision approach navigation shall not exceed 19.6 m, 2drms, when HDOP is normalized to 1.5.

"Notes:

- 1) *The assumptions are as follows: signal-in-space pseudorange accuracy of 6.0 m, 1 sigma and avionics pseudorange accuracy of no more than 2.6 m, 1 sigma (due to receiver noise at minimum signal level, multipath, etc), for a total (root-sum-square) pseudorange accuracy of 6.5 m, 1 sigma. The receiver noise accuracy at minimum signal level is assumed to be no worse than 0.4 m, 1 sigma. The multipath accuracy is assumed to be no worse than 0.7 m, 1 sigma. The dual-frequency ionospheric delay compensation (as a function of pseudorange measurements corrupted by receiver noise and multipath) accuracy is assumed to be no worse than 1.2 m, 1 sigma. The tropospheric delay compensation model accuracy is assumed to be no worse than 2.0 m, 1 sigma. The dynamic propagation and related accuracy is assumed to be no worse than 0.5 m, 1 sigma. Inaccuracies due to flight technical error (FTE), waypoint error, and RNAV path*

computation error are not included. The 2drms accuracy is approximately equal to the 95th percentile accuracy (98.2% - 95.4%).

- 2) *Section 2.5.8 describes the test for this requirement. In order to reduce the duration of testing required to demonstrate accuracy in the presence of the interference conditions, Section 2.5.8 excludes the accuracy effects of the signal-in-space pseudorange error, the multipath error, the tropospheric delay compensation model error, and the dynamic propagation and related error, and uses a dual-frequency sensor pseudorange accuracy threshold of 0.72 meters.*

“In the keyed PPS mode with SA in effect at any level, under the maximum signal conditions defined in Section 2.1.1.10 and interference conditions defined in Appendix C, the horizontal radial position fixing accuracy for non-precision approach navigation shall not exceed 19.4 m, 2drms, when HDOP is normalized to 1.5.

“Notes:

- 1) *The assumptions are as follows: signal-in-space pseudorange accuracy of 6.0 m, 1 sigma and avionics pseudorange accuracy no worse than 2.4 m, 1 sigma (due to receiver noise at maximum signal level, multipath, etc), for a total (root-sum-square) pseudorange accuracy of 6.5 m, 1 sigma. The receiver noise accuracy at maximum signal level is assumed to be no worse than 0.15 m, 1 sigma. The multipath accuracy is assumed to be no worse than 0.70 m, 1 sigma. The dual-frequency ionospheric delay compensation (as a function of pseudorange measurements corrupted by receiver noise and multipath) accuracy is assumed to be no worse than 1.07 m, 1 sigma. The tropospheric delay compensation model accuracy is assumed to be no worse than 2.00 m, 1 sigma. The dynamic propagation and related accuracy is assumed to be no worse than 0.50 m, 1 sigma. Inaccuracies due to flight technical error (FTE), waypoint error, and RNAV path computation error are not included. The 2drms accuracy is approximately equal to the 95th percentile accuracy (98.2% - 95.4%).*
- 2) *Section 2.5.8 describes the test for this requirement. In order to reduce the duration of testing required to demonstrate accuracy in the presence of the interference conditions, Section 2.5.8 excludes the accuracy effects of the signal-in-space pseudorange error, the multipath error, the tropospheric delay compensation model error, and the dynamic propagation and related error, and uses a dual-frequency sensor pseudorange accuracy threshold of 0.27 meters and a single-frequency sensor pseudorange accuracy threshold of 0.15 meters.*

“In the PPS-LO mode and in the unkeyed PPS mode with SA in effect at the level described in Appendix B, under the minimum signal conditions defined in Section 2.1.1.10 and interference

conditions defined in Appendix C, the horizontal radial position fixing error for non-precision approach navigation shall not exceed 100 m, 2drms, when HDOP is normalized to 1.5.

“Notes:

- 1) *The assumptions are as follows: signal-in-space pseudorange accuracy of 33 m, 1 sigma (due primarily to SA) and avionics pseudorange accuracy of no more than 5 m, 1 sigma (due to receiver noise at minimum signal level, multipath, etc), for a total (root-sum-square) pseudorange accuracy of 33.3 m, 1 sigma. Inaccuracies due to flight technical error (FTE), waypoint error, and RNAV path computation error are not included. The 2drms accuracy is approximately equal to the 95th percentile accuracy (98.2% - 95.4%).*
- 2) *Section 2.5.8 describes the test for this requirement. In order to reduce the duration of testing required to demonstrate accuracy in the presence of the interference conditions, Section 2.5.8 excludes the accuracy effects of the signal-in-space pseudorange error (SA and single-frequency ionospheric delay compensation model), the multipath error, the tropospheric delay compensation model error, and the dynamic propagation and related error, and uses a sensor pseudorange accuracy threshold of 5 meters.*

“If a time output is provided, it shall be within 1 second of coordinated universal time (UTC) regardless of operating mode.”

(44) Availability. In lieu of the requirements in paragraph 2.1.3.2.2.2.5 of RTCA/DO-229B, substitute the following requirements:

"The availability of the FDE algorithm to meet the above requirements with an HAL of 0.3 NM, when evaluated over the constellations and grids specified in the test procedures for Case 0 of Section 2.5.9 (i.e., keyed PPS mode, and SA operating as described in Appendix B), using the same satellite selection algorithm used by the equipment and a physically imposed mask angle of 2 degrees shall be greater than or equal to the following:

Availability of detection:	99.990%
Availability of exclusion:	99.400%

"The availability of the FDE algorithm to meet the above requirements with an HAL of 0.3 NM, when evaluated over the constellations and grids specified in the test procedures for Case 1 of Section 2.5.9 (i.e., in the PPS-LO mode or unkeyed PPS mode, and SA operating as described in Appendix B), using the same satellite selection algorithm used by the equipment and a physically imposed mask angle of 5 degrees shall be greater than or equal to the following:

Availability of detection:	97.060%
Availability of exclusion:	57.300%

"The availability of the FDE algorithm to meet the above requirements with an HAL of 0.3 NM, when evaluated over the constellations and grids specified in the test procedures for Case 2 of Section 2.5.9 (i.e., in the PPS-LO mode or unkeyed PPS mode, and SA set to zero), using the same satellite selection algorithm used by the equipment and a physically imposed mask angle of 5 degrees shall be greater than or equal to the following:

Availability of detection:	99.700%
Availability of exclusion:	92.000%

"Note: These requirements are intended to provide a means to assess the adequacy of FDE algorithms. These numbers are based on simulation and analysis of the practical availability and are intended to ensure a consistent minimum capability that can be used by airspace planners and by aircraft operation directors. These availabilities have not been determined to meet all civil operational requirements."

(45) Airborne Equipment Performance - Environmental Conditions. Add the following requirements to the requirements in Section 2.4 of RTCA/DO-229B:

"For GPS/PPS equipment identified with the MSO-C145 marking and certified to Class Beta-1 or to Class Beta-2 requirements, none of the environmental conditions, tests, and performance requirements in this subsection shall be deemed to supercede any environmental condition, test, or performance requirement specified by the prime item specification(s) applying to the particular component of the GPS/PPS navigation sensor. Manufacturers are encouraged to demonstrate satisfaction of the tests in this subsection by analysis when the relevant environmental condition, test, or performance requirement imposed by the prime item specification is more rigorous than the environmental condition, test, or performance requirement imposed by this subsection. Alternative environmental conditions, tests, or performance requirements may be used if they provide an equivalent evaluation of the GPS/PPS equipment.

"It is recognized that the environmental conditions, tests, and performance requirements imposed by this subsection may not be universally applicable to all possible types of GPS/PPS equipment eligible to be identified with the MSO-C145 marking and certified to Class Beta-1 or to Class Beta-2 requirements. One such example is a GPS/PPS receiver card designed to be embedded within a separate line replaceable unit (LRU) where that LRU provides environmental protection for the embedded GPS/PPS receiver card. Manufacturers deviating from the environmental conditions, tests, and performance requirements imposed by this subsection shall demonstrate compliance with the appropriate prime item specification(s)."

(46) Standard Test Signals and Simulator Requirements. In lieu of the requirements in paragraph 2.5.c.(1) of RTCA/DO-229B, substitute the following requirements:

"(1) The GPS satellite simulator shall operate in accordance with the GPS PPS Performance Standard, Edition 1, the GPS SPS Performance Standard, ICD-GPS-200, and ICD-GPS-226."

(47) Standard Test Signals and Simulator Requirements. In lieu of the requirements in paragraph 2.5.c.(2) of RTCA/DO-229B, substitute the following requirements:

"(2) The test signals presented to the unit under test, unless otherwise specified, shall be the minimum input signal at the receiver port or antenna port, as specified in 2.1.1.10. If the manufacturer chooses to be interoperable with the standard SPS antenna as specified in RTCA/DO-228, the minimum input power at the receiver port is -136 dBm for L1 C/A-code, -139 dBm for L1 P(Y)-code, and -142 dBm for L2 P(Y)-code. If the prime item specification for the GPS/PPS receiver specifies a particular antenna to be used or to be assumed, the minimum input power at the receiver port shall be in accordance with the minimum power specified for the particular antenna less the maximum cable loss allowed for installations of that antenna. If the manufacturer chooses to include the antenna and preamplifier as a component of his equipment, a suitable configuration shall be used to yield the minimum signal power at the antenna port; i.e., the maximum cable loss shall be assumed. See Figures 2-18 and 2-19 for L1 C/A-Code examples "

(48) Table 2-19, Test Cross Reference Matrix. Delete the rows associated with the following requirement paragraphs: 2.1.1.3.1, 2.1.1.3.2, 2.1.1.3.3, 2.1.1.4, 2.1.1.4.1, 2.1.1.4.2, 2.1.1.4.3, 2.1.1.4.4, 2.1.1.4.5, 2.1.1.4.6, 2.1.1.4.7, 2.1.1.4.9, 2.1.1.4.10, 2.1.1.4.11, 2.1.1.4.12, 2.1.1.5.2, 2.1.1.5.3, 2.1.1.5.4, 2.1.1.8.2, 2.1.2.2.2.1, 2.1.3.2.2.1, 2.1.3.8, and 2.1.3.9. Delete the rows associated with the following requirement sections: 2.1.4, and 2.2.

(49) Initial Acquisition Test Procedures. Delete the requirements related to Scenario #2 in Section 2.5.4 of RTCA/DO-229B and adjust the pass/fail criteria accordingly.

(50) Satellite Reacquisition Time Test. Delete the requirements related to Scenario #2 in Section 2.5.6 of RTCA/DO-229B and adjust the pass/fail criteria accordingly.

(51) Interference Rejection Test. Add the following requirement to paragraph 2.5.7 (i.e., the introductory paragraph of Section 2.5.7) of RTCA/DO-229B as follows:

"This interference rejection test shall be repeated two times: (1) once in the keyed PPS mode and (2) once in the PPS-LO mode/unkeyed PPS mode. Signal power levels are referenced to L1 C/A-Code. Interference shall be applied at both L1 and L2."

(52) Accuracy Tests. Add the following requirement to paragraph 2.5.8 (i.e., the introductory paragraph of Section 2.5.8) of RTCA/DO-229B as follows:

"These accuracy tests shall be repeated three times: (1) once in the keyed PPS mode, (2) once in the keyed PPS mode with single-frequency operation, and (3) once in the PPS-LO/unkeyed PPS mode. Signal power levels are referenced to L1 C/A-Code. Interference shall be applied at both L1 and L2. Installations with SATCOM shall be assumed."

(53) Simulator and Interference Conditions. Replace the second note related to the total number of tests in paragraph 2.5.8.1.1 of RTCA/DO-229B as follows.

Delete the existing text which reads:

"Note: The entire steady-state accuracy test will include a total of twelve cases to be tested (thirteen for equipment installed on aircraft with SATCOM): a GPS-only case with minimum GPS RF power and pulsed interference conditions of Table 2-25, nine GPS-WAAS cases (ten for equipment installed on aircraft with SATCOM) with minimum RF power and with the interference conditions listed in Table 2-23, Table 2-24, Table 2-25, and two GPS-WAAS cases with maximum RF power and with the broadband interference conditions listed in Table 2-23."

Insert new text which reads:

"Note: The entire steady-state accuracy test for each mode (keyed PPS mode, PPS-LO mode/unkeyed PPS mode) will include a total of twelve cases to be tested: ten cases (SATCOM assumed) with minimum GPS RF power and with the interference conditions listed in Table 2-23, Table 2-24, and the middle column of Table 2-25; and two cases with maximum GPS RF power and with the broadband interference condition listed in Table 2-23."

(54) Test Procedures. Replace the note in paragraph 2.5.8.1.2.(5)a. of RTCA/DO-229B as follows:

Delete the existing text which reads:

"Note The sampling interval will be two times longer than the integration interval used for carrier phase smoothing of pseudoranges. For example, if the integration interval used for carrier smoothing of the pseudoranges is 100 second, the sampling interval will be 200 seconds. If ten pseudoranges are collected per sampling interval (nine independent measurements), the duration of the initial data collection period will be 20 minutes."

Insert new text which reads:

"Note In single-frequency operation, the sampling interval will be two times longer than the integration interval used for carrier phase smoothing of the pseudoranges. For example, if the integration interval used for carrier smoothing of the pseudoranges is 100 seconds, the sampling interval will be 200 seconds. If ten pseudoranges are collected per sampling interval (nine independent

measurements), the duration of the initial data collection period will be 20 minutes. In dual-frequency operation, the sampling interval will be two times longer than the longer of either the integration interval used for carrier phase smoothing of the pseudoranges or the integration interval used for smoothing of the inter-frequency pseudorange differences."

(55) Test Procedures. In lieu of the requirements in paragraph 2.5.8.1.2.(5)d. of RTCA/DO-229B, substitute the following requirements:

"The average $\sigma_{noise,ij}$ output values for each satellite, $\sigma_{noise,i,ave}$, are compared to the derived requirements of Section 2.1.2.1 for Class 1 equipment, and compared to the derived requirements of Section 2.1.3.1 for Class 2 equipment. The output values must be less than or equal to the required accuracy values. A summary table for Class 1 and 2 equipment in the keyed PPS mode is provided in Table 2-27. For Class 1 and 2 equipment in the PPS-LO and unkeyed PPS modes, the required accuracy value is 5 meters."

(56) Table 2-27. In lieu of Table 2-27 of RTCA/DO-229B, substitute the following table.

Table 2-27 CLASS 1 AND 2 SIGMA NOISE CRITERIA

Mode/Configuration	Maximum $\sigma_{noise,i,ave}$ Value
Keyed PPS, dual-frequency, minimum signal level	0.72 meters
Keyed PPS, dual-frequency, maximum signal level	0.27 meters
Keyed PPS, single-frequency, minimum signal level	0.40 meters
Keyed PPS, single-frequency, maximum signal level	0.15 meters

(57) GPS Constellation. In lieu of the requirements in paragraph 2.5.9.1.2 of RTCA/DO-229B, substitute the following requirements:

"The GPS satellite constellation to be used in the simulation shall be the 24 satellite constellation defined in Appendix B. In all tests, the satellite selection algorithm and the number of channels shall be the same as that used by the equipment. In the keyed PPS mode, the mask angle shall be 2 degrees regardless of the mask angle of the particular equipment under test in this mode. In the PPS-LO mode and in the unkeyed PPS mode, the mask angle shall be 5 degrees regardless of the mask angle of the particular equipment under test in these modes."

(58) Availability Tests. In addition to the requirements in paragraph 2.5.9.2 of RTCA/DO-229B, add the following requirement:

"Case 0: Regardless of SA in the keyed PPS mode, a one-sigma User Equivalent Range Error (UERE) of 6.5 m shall be assumed."

(59) Availability Tests. Replace the requirements relating to Case 1 and Case 2 in paragraph 2.5.9.2 of RTCA/DO-229B as follows.

Delete the existing text which reads:

"Case 1: In the presence of SA, the effect on the User Equivalent Range Error (UERE) shall be modeled as specified in Appendix B.

Case 2: In the absence of SA, a one-sigma UERE of 12.5 m shall be assumed."

Insert new text which reads:

"Case 1: In the presence of SA in the PPS-LO mode and in the unkeyed PPS mode, the effect on the User Equivalent Range Error (UERE) shall be modeled as specified in Appendix B.

Case 2: In the absence of SA in the PPS-LO mode and in the unkeyed PPS mode, a one-sigma UERE of 12.5 m shall be assumed."

(60) Availability Tests. Delete the requirement relating to a 5-degree mask angle in paragraph 2.5.9.2 of RTCA/DO-229B.

(61) Off-Line FDE Tests. Add the following requirement to paragraph 2.5.9.3 (i.e., the introductory paragraph of Section 2.5.9.3) of RTCA/DO-229B as follows:

"The off-line FDE tests shall be repeated two times: (1) once in the keyed PPS mode and (2) once in the PPS-LO mode/unkeyed PPS mode."

(62) False Alert Rate Test. Add the following requirement to paragraph 2.5.9.4 (i.e., the introductory paragraph of Section 2.5.9.4) of RTCA/DO-229B as follows:

"The false alert rate test shall be repeated two times: (1) once in the keyed PPS mode and (2) once in the PPS-LO mode/unkeyed PPS mode."

(63) False Alert Rate Test For Snapshot Algorithms. Replace the requirements relating to the pass criteria in paragraph 2.5.9.4.1 of RTCA/DO-229B as follows.

Delete the existing text which reads:

"1. The total number of alerts over all admissible geometries shall be equal to or less than 47.

"2. For each geometry, there shall be no more than 3 alerts."

Insert new text which reads:

"1. The total number of alerts over all admissible geometries shall be equal to or less than 9400 in the keyed PPS mode, equal to or less than 47 in the PPS-LO mode, and equal to or less than 47 in the unkeyed PPS mode.

"2. For each geometry, there shall be no more than 600 alerts in the keyed PPS mode, no more than 3 alerts in the PPS-LO mode, and no more than 3 alerts in the unkeyed PPS mode."

"Note: The number of false alerts for keyed PPS mode is 200 times larger than in the PPS-LO and the unkeyed PPS mode on a per-sample basis. The correlation time for naturally occurring PPS errors is 200 times larger than the artificially induced errors caused by SA. These two offsetting factors result in the same false alert rate on a per-hour basis ($10^{-5}/hr$)."

(64) False Alert Rate Test For Non-Snapshot Algorithms. Replace the note related to the total number of hours in paragraph 2.5.9.4.2 of RTCA/DO-229B as follows.

Delete the existing text which reads:

"Note: The false alert rate for non-snapshot algorithms cannot be easily converted into a false alert probability. For these algorithms, a total number of 3,300,000 hours of operation has to be simulated to gain statistical confidence. During this simulation, no more than 47 false alerts can be allowed for the equipment to pass the test.

Insert new text which reads:

"Note: The false alert rate for non-snapshot algorithms cannot be easily converted into a false alert probability. For these algorithms, a total number of 3,300,000 hours of operation has to be simulated to gain statistical confidence. Because the satellite positions are frozen for these tests, the simulation must model the correlated effect of the satellite signal-in-space errors over the correlation time. In the keyed PPS mode simulation, the assumed signal-in-space correlation time due to naturally occurring errors is 6.67 hours. In the PPS-LO mode simulation and in the unkeyed PPS mode simulation, the assumed signal-in-space correlation time due to SA errors is 2 minutes. During each of these simulations, no more than 47 false alerts can be allowed in each mode for the equipment to pass the test.

(65) On-Target Computational Test. Add the following requirement to paragraph 2.5.9.5.1 of RTCA/DO-229B as follows:

"The on-target computational test shall be repeated three times: (1) once in the keyed PPS mode, (2) once in the PPS-LO mode, and (3) once in the unkeyed PPS mode."

(66) On-Line Behavioral Test. In lieu of the requirements in paragraph 2.5.9.5.2 of RTCA/DO-229B, substitute the following requirements:

"The behavioral tests will be conducted on the GPS/PPS equipment using a satellite simulator. Five groups of behavioral tests will be conducted: (1) tests in the keyed PPS mode with SA set to zero, (2) tests in the PPS-LO mode with SA set to zero, (3) tests in the PPS-LO mode with SA set as described in Appendix B, (4) tests in the unkeyed PPS mode with SA set to zero, and (5) tests in the unkeyed PPS mode with SA set as described in Appendix B. The purpose of the SA set to zero tests are to ensure that the behavior of the GPS/PPS equipment and the off-line tests are functionally and computationally similar. The purpose of the SA set as described in Appendix B tests are to ensure that the GPS/PPS equipment can properly function in a noise environment.

"Each group of behavioral tests shall be run using five constellation geometries selected from the sets of forty used under Section 2.5.9.5.1 that have a relatively constant HPL_{FD} and HEL_{FD} for the duration of the test. A ramp failure shall be generated as defined in Section 2.5.9.3.3 in each case. All test scenarios will be conducted with the GPS/PPS equipment stationary (non-dynamic).

"In order to pass the three groups of SA set to zero tests (1, 2, and 4):

- "1. The equipment position fixing difference shall only exceed 5 meters for periods of 2 seconds or less.
- "2. The equipment HPL_{FD} difference shall only exceed 50 meters for periods of 10 seconds or less.

"If these thresholds are exceeded, the cause of the difference shall be identified and that cause must be within the expected characteristics of the algorithm.

"In order to pass the SA set as described in Appendix B tests (3 and 5), each SA set as described in Appendix B failure shall be matched with a corresponding SA set to zero failure for the same geometry."

(67) Coverage. In lieu of the requirements in paragraph 3.1.2.2 of RTCA/DO-229B, substitute the following requirements:

"No matter where the aircraft is on or near the surface of the Earth, the installed equipment shall meet applicable performance requirements of Section 2. This shall include bank angles of up to 30 degrees and pitch angles associated with approaches and departures.

"Note: This equipment may experience loss of lock and positioning errors when maneuvering with greater than 30 degrees of bank."

(68) Appendix B, Selective Availability. In lieu of the requirements in paragraph B.3 of RTCA/DO-229B, substitute the following requirements:

"Selective availability shall be modeled as specified in ICD-GPS-226 such that the total pseudorange error due to SA shall be modelable as a Gaussian random variable with a long-term mean of zero and a standard deviation of 33 m."

(69) Appendix C, Introduction. Add the following information to paragraph C.1 (i.e., the introductory paragraph of Appendix C) of RTCA/DO-229B:

"All signal power levels are referenced to L1 C/A-Code.

"Note: The interference levels specified in this appendix are not expected to affect GPS/PPS equipment operating in the keyed PPS mode except perhaps during acquisition."

(70) Appendix G, Introduction. Add the following note to paragraph G.1 (i.e., the introductory paragraph of Appendix G) of RTCA/DO-229B:

"Note: This appendix describes requirements for a particular set of barometric altimeter aiding algorithms. Alternative sets of barometric altimeter aiding algorithms may be used provided they comply with similar requirements and offer an equivalent level of safety. An acceptable alternative set of barometric altimeter aiding algorithms is described in MSO-C129."

c. Functional Qualifications. The required performance shall be demonstrated under the test conditions specified in RTCA/DO-229B, Section 2.5. The use of test procedures other than those specified in Sections 2.5.3 through 2.5.9 of RTCA/DO-229B, except as specified herein, constitutes a deviation to this MSO.

d. Environmental Qualifications. The equipment shall be subject to the test conditions as specified in RTCA/DO-160D, "Environmental Conditions and Test Procedures for Airborne Equipment", except as specified herein.

e. Software Qualifications. If the article includes software, the software must be developed in accordance with or a method comparable to Sections 3-11, Annex A, and Annex B of RTCA/DO-178B, "Software Considerations in Airborne Systems and Equipment Certification", dated December 1, 1992. If the software is qualified using criteria contained in Section 2 or Section 12 of DO-178B, MSO applicants must apply for a deviation to this MSO. Deviations are more likely to be approved if the software levels are adequately substantiated in the safety assessment.

5. MARKING. In addition to the markings specified in 14 CFR § 21.607(d), recognizing that the governing document in this case is an MSO rather than a TSO, the following requirements apply to all separate components of equipment that are manufactured under this MSO:

- a. At least one major component must be permanently and legibly marked with all of the information listed in 14 CFR § 21.607(d).
- b. Each separate component of equipment must be permanently and legibly marked with at least the name of the manufacturer, manufacturer's part number, and the MSO number.
- c. If the component includes software, the part number must include hardware and software identification, or separate part numbers may be utilized for hardware and software. The part number must uniquely identify the hardware and software design, including modification status.
- d. The operational equipment class as defined in Section 1 of RTCA/DO-229B (e.g., Class Beta-2).
- e. When applicable, identification that the article is an incomplete system or that the article accomplishes additional functions beyond the minimum described in paragraphs 2, 3, and 4 of this MSO.
- f. If these are multiple components that are interdependent and not interchangeable, they shall be match as a matched set.

6. DATA REQUIREMENTS.

a. Data to be provided with the application. In addition to documents specified in 14 CFR §§ 21.605(a)(1) and (3) and in accordance with § 21.605(a)(2), recognizing that the governing document in this case is an MSO rather than a TSO, the manufacturer must furnish the PPS Equipment Certification Office (PECO) at the GPS Joint Program Office one copy each of the following technical data to support the design and production approval:

(1) Operating instructions and equipment limitations. The limitations shall be sufficient to describe the operational capability of the equipment. The limitations shall be sufficient to ensure that the article, when operated in accordance with the operating instructions, continues to meet the requirements of this MSO. The limitations shall also be sufficient to identify any unique operating aspects. The limitations shall include at least the following:

(a) Adequate specification of the equipment operating mode or modes and the effect (if any) on the interface between the GPS/PPS navigation sensor and other systems to ensure proper functioning of the integrated system. This must include the definition of all equipment operating modes, mode switching controls, mode configuration monitoring, and identification of which modes are default.

If the equipment has not been demonstrated to satisfy the requirements of this MSO when operated in all operating modes, each operating mode shall be explicitly identified.

(b) If the equipment has only been demonstrated to satisfy the requirements of this MSO when operated in a certain mode or modes (e.g., a mode in which the output position information is not referenced to WGS-84), then the limitations shall include a note with the following statement:

“The conditions and tests required for MSO approval of this article have not been demonstrated in every mode of which the article is capable of operating in. It is the responsibility of those desiring to install this article either on or within a specific type or class of aircraft to determine that the article, when installed and operated in any normal mode for that type or class of aircraft, performs in accordance with the design specifications that meet this MSO. The article may be used for navigation purposes in RNP RNAV airspace only if further evaluation documents an acceptably low probability of inadvertent aircrew use of position information from the article operating in a non-MSO mode. This evaluation will be conducted by the appropriate Operational Approval authority (e.g., Air Force Flight Standards Agency).”

(2) Installation procedures and limitations. The limitations shall be sufficient to ensure that the article, when installed in accordance with the installation procedures, continues to meet the requirements of this MSO. The limitations shall also be sufficient to identify any unique aspects of the installation. The limitations shall include at least the following:

(a) A note with the following statement:

“The conditions and tests required for MSO approval of this article are minimum performance standards. It is the responsibility of those desiring to install this article either on or within a specific type or class of aircraft to determine that the article, when installed, performs in accordance with the design specifications that meet this MSO. The article may be installed only if further evaluation by the applicant documents an acceptable installation and is approved by the appropriate Service airworthiness certification authority, e.g., GATO/MC2 System Program Office for the Air Force, AMRDEC/AED for the Army, and OPNAV N78 for the Navy.”

(b) Adequate specification of the interface between the GPS/PPS navigation sensor and other systems to ensure proper functioning of the integrated system. This must include maximum tolerable currents and voltages into the antenna port.

(c) If the equipment has only been demonstrated to satisfy the requirements of this MSO when used in conjunction with a particular antenna, the use of that antenna (by part number) must be specified as a limitation.

(d) If the equipment is dependent on any inputs in order to satisfy the requirements of this MSO besides PPS cryptokeys and a SPS/PPS switching source, those inputs should be made a requirement on the installation (i.e., a limitation).

(e) When applicable, identification that the article is an incomplete system or a multi-use system. This must describe the functions that are intended to be provided by the article. Any omitted PPS-LO mode functionality or any added WAAS or SBAS satellite functionality shall be explicitly identified.

(3) Schematic drawings as applicable to the installation procedures.

(4) Wiring drawings as applicable to the installation procedures.

(5) Specifications, particularly including the prime item specification.

(6) List of the components (by part number) that make up the equipment system complying with the standards prescribed in this MSO.

(7) Instructions for periodic maintenance and calibration that are necessary for continued airworthiness.

(8) An environmental qualifications form as described in RTCA/DO-160D for each component of the system.

(9) Manufacturer's MSO qualification test report.

(10) Nameplate drawing.

(11) A drawing list, enumerating all of the drawings and processes that are necessary to define the article's design.

(12) If the article includes software: Plan for Software Aspects of Certification (PSAC), Software Configuration Index, and Software Accomplishment Summary.

NOTE: The PECO recommends that the PSAC be submitted early in the software development process. Early submittal will allow timely resolution of issues such as partitioning and determination of software levels.

(13) Proposed deviations and waivers, if any. (In particular, see paragraphs 4.b.(27), 4.b.(28), and 4.c. in this MSO.)

b. Data that must be available upon request. In addition to those data requirements that are to be furnished directly to the PECO, each manufacturer must have available for review by the PECO, the following technical data:

(1) The functional qualification specifications to be used to qualify each production article to ensure compliance with this MSO.

(2) Qualification test procedures used to determine compliance with this MSO.

(3) Equipment calibration procedures.

(4) Corrective maintenance procedures (within 12 months after MSO authorization).

(5) Schematic drawings.

(6) Wiring diagrams.

(7) The results of the environmental qualification tests conducted in accordance with RTCA/DO-160D.

(8) If the article includes software, the appropriate documentation as defined in RTCA/DO-178B, including all data supporting the applicable objectives found in Annex A of RTCA/DO-178B, Process Objectives and Outputs by Software Level.

(9) Host Application Equipment (HAE) design security approval documentation and any imposed limitations.

c. Data to be Furnished with Manufactured Units.

(1) One copy of the data and information specified in paragraphs 6(a)(1) through (8) of this MSO must be provided to each purchaser of one or more articles manufactured under this MSO.

(2) If the article accomplishes any additional functions beyond that described in paragraph 2 of this MSO, then a copy of the data and information specified in paragraphs 6(a)(9) through (12) must also be provided to each purchaser of one or more articles manufactured under this MSO.

7. AVAILABILITY OF REFERENCED DOCUMENTS.

a. Copies of RTCA/DO-160D, DO-178B, and DO-229B may be purchased from RTCA Inc., 1828 L Street, NW, Suite 805, Washington, D.C. 20036.

b. 14 CFR § 21, Subpart O, may be purchased from the Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325. AC 20-110 (current revision), "Index of Aviation Technical Standard Orders," and AC 20-115 (current revision), TSO-C145, "Radio Technical Commission for Aeronautics, Inc., Document RTCA/DO-178B," may be obtained from the U.S. Department of Transportation, Subsequent Distribution Office, Ardmore East Business Center, 3341 Q 75th Ave, Landover, MD 20785.

c. Copies of the current editions of the GPS PPS Performance Standard, Edition 1, the GPS SPS Performance Standard, ICD-GPS-200, ICD-GPS-226, MSO-C144, MSO-C129a may be obtained from the Administrative Contracting Officer for the procurement, or from the PECO at SMC/CZU (Attn: PECO), 2420 Vela Way, Suite 1467, El Segundo, CA 90245-4659.

Acting Manager, PECO,
GPS Joint Program Office (AFSPC)

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