



Department of Transportation
Federal Aviation Administration
Aircraft Certification Service
Washington, D.C.

TSO-C146c

Effective
Date: 05/09/08

Technical Standard Order

Subject: Stand-Alone Airborne Navigation Equipment Using The Global Positioning System Augmented By The Satellite Based Augmentation System

1. **PURPOSE.** This technical standard order (TSO) is for manufacturers applying for a TSO authorization (TSOA) or letter of design approval (LODA). In it, we (the Federal Aviation Administration, or FAA) tell you what minimum performance standards (MPS) your stand-alone airborne navigation equipment using the global positioning system (GPS) augmented by the satellite based augmentation system (SBAS) must first meet for approval and identification with the applicable TSO marking.

NOTE: This revision eliminates the 3dB broadband external interference noise credit in the previous MPS for operational Class 1 and Class 2 equipment.

2. **APPLICABILITY.** This TSO affects new applications submitted after its effective date.

a. All prior revisions to this TSO are no longer effective. We will not accept applications for Class Gamma 1 and Class Gamma 2 equipment that claims the 3dB noise credit based on the earlier MPS after the effective date of this TSO. However, we will work with you to resolve the noise credit issue up to six months after the effective date of this TSO if we know that you were working against the earlier MPS. For Class Gamma 3 and Class Delta 4 (and Class Gamma 1 or Gamma 2 that does not claim the noise credit) we will automatically convert your application to TSO-C146c. Class Gamma 3 and Class Delta 4 equipment (and Class Gamma 1 or Gamma 2 that does not claim the noise credit) previously approved under TSO-C146b fully complies with the requirements of this TSO.

b. Stand-alone GPS/SBAS equipment approved under TSO-C146a may still be manufactured under the provisions of their original approval. Class Gamma 3 and Class Delta 4 equipment (and Gamma Class 1 and Class 2 equipment that did not claim the 3dB credit) approved under TSO-C146b may still be manufactured under the provisions of their original approval.

c. Major design changes to stand-alone GPS/SBAS equipment approved under this TSO will require a new authorization. See Title 14 of the Code of Federal Regulations (14 CFR) § 21.611(b).

3. **REQUIREMENTS.** New models of stand-alone GPS/SBAS equipment identified and manufactured on or after the effective date of this TSO must meet the MPS qualification and documentation requirements for functional equipment Class Gamma or Delta in RTCA, Inc. document RTCA/DO-229D, *Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment*, dated December 13, 2006, Section 2, except as modified in appendix 1 of this TSO. Classes Gamma and Delta equipment are defined in RTCA/DO-229D, Section 1.4.

a. **Functionality.** This TSO's standards apply to equipment intended to accept a desired flight path and provide deviation commands keyed to that path. Pilots and autopilots will use these deviations to guide the aircraft. Except for automatic dependent surveillance, these TSO standards don't address integration issues with other avionics, such as whether the stand-alone GPS/SBAS equipment could inadvertently command an autopilot hardover.

b. **Failure Condition Classification.**

(1) Failure of the function defined in paragraph 3.a of this TSO is a:

- *Major* failure condition for loss of function and malfunction of en route, terminal, approach lateral navigation (LNAV), and approach LNAV/vertical navigation (VNAV) navigation data,
- *Major* failure condition for loss of function of approach localizer performance without vertical guidance (LP), and approach localizer performance with vertical guidance (LPV) navigation data, and
- *Hazardous* failure condition for malfunction of approach (LP and LPV) navigation data.

(2) Develop the system to, at least, the design assurance level equal to these failure condition classifications.

c. **Functional Qualification.** Demonstrate the required performance under the test conditions and procedures specified in RTCA/DO-229D, Section 2.5.

d. **Environmental Qualification.** Test the equipment according to RTCA/DO-229D, Section 2.4 and RTCA/DO-160E, *Environmental Conditions and Test Procedures for Airborne Equipment*, dated December 9, 2004, Sections 4.0 through 8.0 and 10.0 through 25.0.

e. Software Qualification. If the article includes a digital computer, develop the software according to RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*, dated December 1, 1992, Sections 2 through 12 and Annex A. The software design assurance level should be consistent with the failure condition classifications defined in paragraph **3.b** of this TSO.

f. Electronic Hardware Qualification. If the article includes a complex custom micro-coded component, develop the component to the guidance in FAA Advisory Circular (AC) 20-152, *RTCA, Inc. Document RTCA/DO-254, Design Assurance Guidance for Airborne Electronic Hardware*. The hardware design assurance level should be consistent with the failure condition classifications defined in paragraph **3.b** of this TSO.

g. Barometric-Aided Fault Detection and Exclusion (FDE). If the equipment uses barometric-aiding to enhance the availability of FDE, then the equipment must meet the requirements in RTCA/DO-229D, Appendix G.

h. Deviations. We have provisions for using alternate or equivalent means of compliance to the criteria in the MPS of this TSO. If you invoke these provisions, you must show that your equipment maintains an equivalent level of safety. Apply for a deviation under 14 CFR § 21.609 before submitting your data package.

4. MARKING.

a. Mark at least one major component permanently and legibly with all the information in 14 CFR § 21.607(d).

b. Also, mark the following permanently and legibly, with at least the manufacturer's name, subassembly part number, and the TSO number:

- (1) Each component that is easily removable (without hand tools),
- (2) Each interchangeable element, and
- (3) Each subassembly of the article that you determined may be interchangeable.

c. If the component includes a digital computer, then the part number must include hardware and software identification. Or, you can use a separate part number for hardware and software. Either way, you must include a means to show the modification status.

NOTE: Similar software versions, approved to different software levels, must be differentiated by part number.

d. When applicable, identify the equipment as an incomplete system or state that the article performs functions beyond those described in paragraph **3.a** of this TSO.

e. At least one major component must be permanently and legibly marked with the operational equipment class (such as Class 2) as defined in RTCA/DO-229D, Section 1.4.2. Marking the equipment Class 4 indicates compliance to Delta Class 4 requirements. There is no requirement to mark the functional equipment class (for example, Gamma and Delta) defined in Section 1.4.1 of RTCA/DO-229D.

5. APPLICATION DATA REQUIREMENTS. As a TSO manufacturer-applicant, you must give the FAA aircraft certification office (ACO) manager responsible for your facilities a statement of conformance, as specified 14 CFR § 21.605(a)(1) and one copy each of the following technical data to support our design and production approval. (Under 14 CFR § 21.617(a)(2), LODA applicants submit the same data through their civil aviation authority:)

a. Operating instructions and equipment limitations in an installation/instruction manual (IM), sufficient to describe the equipment's operational capability. Describe any deviations in detail. If needed, identify equipment by part number, version, revision, and criticality level of software/hardware, classification for use, and environmental categories. For Class 1, 2, and 3 equipment, include in the operating instructions:

(1) An operations manual for using the equipment.

(2) A training package on using the equipment. This training package may be in any medium (video, software, and paper) and should familiarize an operator with all the functions and operation of the equipment.

(3) A quick-reference guide with instructions how to do (at least) the following:

- Enter a flight plan,
- Edit a flight plan,
- Execute a Direct-TO,
- Accomplish a holding pattern,
- Execute an approach procedure, and
- Execute a missed approach.

b. Installation procedures and limitations in an IM, sufficient to ensure that the stand-alone GPS/SBAS equipment, when installed according to the installation procedures, still meets this TSO's requirements. Limitations must identify any unique aspects of the installation. Finally, the limitations must include a note with the following statement:

The conditions and tests required for TSO approval of this article are minimum performance standards. Those installing this article,

on or in a specific type or class of aircraft, must determine that the aircraft installation conditions are within the TSO standards. TSO articles must have separate approval for installation in an aircraft. The article may be installed only according to 14 CFR part 43 or the applicable airworthiness requirements.

- c.** Schematic drawings of the installation procedures.
- d.** Wiring diagrams of the installation procedures
- e.** List of major components (such as antenna, control/display computer, navigation computer, and data card) by part number, that make up the stand-alone GPS/SBAS equipment complying with the standards prescribed under this TSO. Include vendor part number cross-references, when applicable.
- f.** Material and process specifications list.
- g.** The quality control system (QCS) description required by 14 CFR §§ 21.143 and 21.605(a)(3), including functional test specifications. The QCS should ensure that you will detect any change to the equipment that could adversely affect compliance with the TSO MPS, and reject them accordingly. (Not required for LODA applicants.)
- h.** Manufacturer's TSO qualification test report.
- i.** Nameplate drawing with the information required by paragraph 4 of this TSO.
- j.** List of all drawings and processes (including revision level) that define the article's design. For a minor change, follow the directions in 14 CFR § 21.611(a). Show any revisions to the drawing list only on our request.
- k.** An environmental qualifications form as described in the environmental qualifications document referenced in paragraph 3.d of this TSO for each component of the system.
- l.** If the article includes a digital computer: a plan for software aspects of certification (PSAC), software configuration index, and software accomplishment summary. We recommend that you submit the PSAC early in the software development process. Early submittal allows us to quickly resolve issues, such as partitioning and determining software levels.
- m.** If the article includes a complex custom micro-coded component: a plan for hardware aspects of certification (PHAC), hardware verification plan, top-level drawing; and hardware accomplishment summary. We recommend that you submit the PHAC early in the hardware development process. Early submittal allows us to quickly resolve issues.

n. A summary of the database updating process that meets the requirements in RTCA/DO-229D, Section 2.2.1.5.3. This summary must define the data quality requirements, identify the data source(s), and briefly describe the data distribution and update process.

o. If the equipment can satisfy the requirements of RTCA/DO-229D only when used with a particular antenna, make the use of that antenna (by part number) a requirement on the installation. Include this requirement in the IM as a limitation.

p. Adequate specifics on the interface between the stand-alone GPS/SBAS equipment and other systems to ensure proper functioning of the integrated system. Include maximum tolerable currents and voltages into the antenna port if the equipment is installed with a standard antenna. See TSO-C144a, *Passive Airborne Global Navigation Satellite System (GNSS) Antenna*, applicable only to operational Class 1 equipment, or TSO-C190, *Active Airborne Global Navigation Satellite System (GNSS) Antenna*, applicable to all equipment operational classes.

q. If the equipment depends on any inputs (like a baro-aided FDE) to satisfy the requirements of RTCA/DO-229D, make those inputs a requirement in the installation. Include this requirement in the IM as a limitation.

r. If the software qualification limits eligibility of the equipment to certain aircraft types, identify the qualification level, and that the equipment is not eligible for all aircraft types. For example, AC 23-1309-1, *Equipment, Systems, and Installations in Part 23 Airplanes*, states that the RTCA/DO-178B Level C software may be associated with a *hazardous* failure condition for certain aircraft types. Identify other limitations applicable to the failure condition classification ---for example, that two installed units are necessary.

s. If the equipment has not been demonstrated as compatible with satellite communications (SatCom), state in the limitations that the equipment should not be installed in SatCom equipped aircraft.

6. MANUFACTURER DATA REQUIREMENTS. Besides the data given directly to us, have the following technical data available for review by the responsible ACO or civil aviation authority:

a. Functional qualification specifications for qualifying each production article to ensure compliance with this TSO.

b. Equipment calibration procedures.

c. Corrective maintenance procedures within 12 months after TSOA or LODA including a component maintenance manual (CMM), covering periodic maintenance, calibration, and repair, for the continued airworthiness of installed stand-alone GPS/SBAS equipment. Include recommended inspection intervals and service life.

- d. Schematic drawings.
- e. Wiring diagrams.
- f. Material and process specifications.
- g. The results of the environmental qualification tests conducted per RTCA/DO-160E.
- h. If the article includes a digital computer, the appropriate documentation defined in RTCA/DO-178B, including all data supporting the applicable objectives in RTCA/DO-178B Annex A, Process Objectives and Outputs by Software Level.
- i. If the article includes a complex custom micro-coded component, the appropriate hardware life cycle data in combination with design assurance level, as defined in RTCA/DO-254, Appendix A, Table A-1.
- j. Qualification test procedures used to determine compliance with this TSO.
- k. Documentation describing the data distribution process in detail, compliant with RTCA/DO-200A, *Standards for Processing Aeronautical Data*, dated September 28, 1998.
- l. All the data necessary to evaluate the geo stationary (GEO) satellite bias as defined in RTCA/DO-229D, Section 2.1.4.1.5.

7. FURNISHED DATA REQUIREMENTS. If furnishing one or more articles manufactured under this TSO to one entity (such as an operator or repair station), provide the following:

- a. One copy of the data in paragraphs **5.a** through **5.e**, **5.k**, **5.o** through **5.s**, and **6.c** of this TSO. Add any other data needed for the proper installation, certification, use, or for continued airworthiness, of the stand-alone GPS/SBAS equipment.
- b. If the article performs functions beyond those described in paragraph **3.a** of this TSO, contact the ACO for guidance on additional data requirements.

8. HOW TO GET REFERENCED DOCUMENTS.

- a. Order RTCA documents from RTCA Inc., 1828 L Street NW, Suite 805, Washington, D.C. 20036. Telephone (202) 833-9339, fax (202) 833-9434. You can also order copies online at www.rtca.org.
- b. Order copies of 14 CFR part 21, Subpart O, from the Superintendent of Documents, Government Printing Office, P.O. Box 37154, Pittsburgh PA 15250-7954. Telephone (202) 512-

1800, fax (202) 512-2250. You can also order copies online at www.access.gpo.gov. Select “Access,” then “Online Bookstore.” Select “Aviation,” then “Code of Federal Regulations.”

c. You can find a current list of technical standard orders and advisory circulars on the FAA Internet website Regulatory and Guidance Library at <http://rgl.faa.gov>. You will also find the TSO Index of Articles at the same site.

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**APPENDIX 1. MPS FOR STAND-ALONE AIRBORNE NAVIGATION EQUIPMENT
USING GPS AUGMENTED BY SBAS**

1. This appendix prescribes modifications to the MPS for functional equipment class Gamma found in RTCA/DO-229D, Section 2. Gamma operational Class 3 and Delta operational Class 4 equipment already complies with the MPS changes below. These MPS changes apply for operational Class 1 or Class 2 equipment only.

a. RTCA/DO-229D. Section 2.5**• Section 2.5.6.1, Scenario #1, Step 3)**

Change step 3) to read: “Broadband external interference noise ($I_{Ext,Test}$) of spectral density equal to -170.5 dBm/Hz at the antenna port.”

• Section 2.5.6.1, Scenario #2, Step 4)

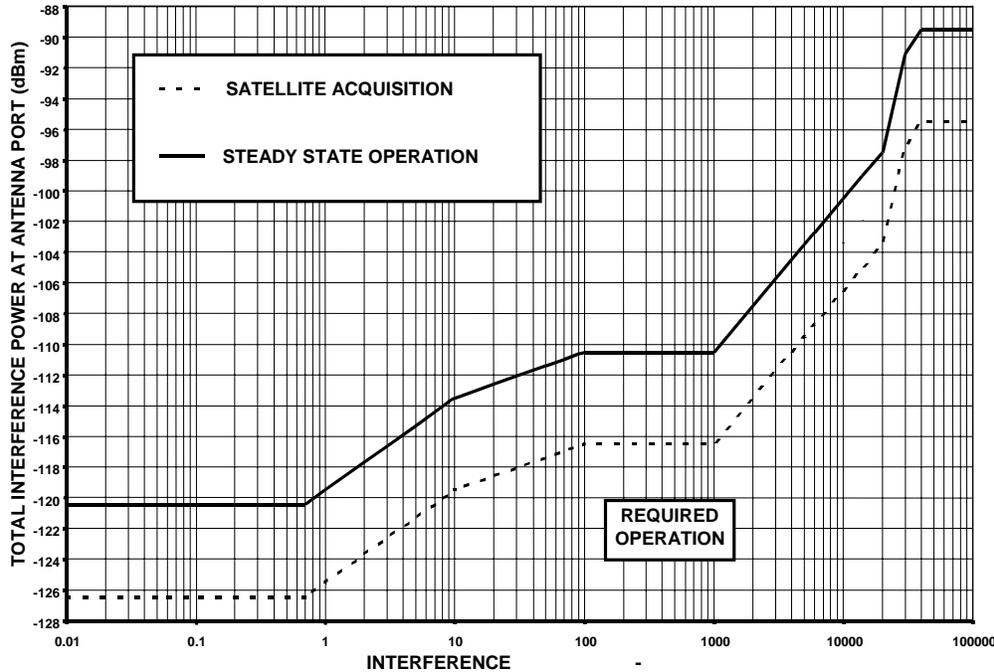
Change step 4) to read: “Broadband external interference noise ($I_{Ext,Test}$) of spectral density equal to -170.5 dBm/Hz at the antenna port.”

• Section 2.5.8.2, Requirement 1), Item a)

Change item a) to read: “The broadband external interference noise ($I_{Ext,Test}$) of spectral density equal to -170.5 dBm/Hz at the antenna port.”

b. RTCA/DO229D, Appendix C, Figure C-2, In-Band and Near-Band Interference Environments

Replace Figure C-2 with the following:



c. RTCA/DO229D, Appendix C, Section C.2.2

- Change the first paragraph to read:

The baseline in-band and near-band interference environments apply to steady-state operation. For initial acquisition of the GPS and SBAS signals prior to steady-state navigation, the in-band and near-band interference levels are 6 dB less than those for steady-state operation. The interference bandwidth is the 3 dB bandwidth.

- Delete the last paragraph in the section (as shown below).

~~The in-band and near-band interference levels for the LNAV approach steady-state navigation operations are 3 dB less than those for LNAV/VNAV, LP, and LPV approach steady-state navigation operations. For terminal area and en-route steady-state navigation operations, and for initial acquisition of the GPS and WAAS signals prior to steady-state navigation for all flight phase operations, the in-band and near-band interference levels are 6 dB less than those for LNAV, LNAV/VNAV, and LPV approach steady-state navigation operations.~~