



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

TSO-C146d

Effective
Date: 12/20/13

Technical Standard Order

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

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, (FAA)) tell you what minimum performance standards (MPS) your stand-alone airborne navigation sensors, 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 provides applicants an option to use a TSO-C205 circuit card assembly (CCA) functional sensor as part of their Class Delta-4 TSO application.

2. **APPLICABILITY.** TSO-C146d is applicable for new applications after December 20, 2013.

a. TSO-C146c will also remain effective until 06/20/2015. After this date we will no longer accept applications for TSO-C146c.

b. We will not accept applications based on an earlier MPS for Class Gamma 1 and Class Gamma 2 equipment that claims the 3dB noise credit. Class Gamma 3 and Class Delta-4 equipment (and Class Gamma 1 or Gamma 2 that does not claim the noise credit) approved to TSO-C146 revision 'b' or 'c' fully complies with the requirements of this TSO.

c. Stand-alone GPS/SBAS equipment approved under a previous TSOA may still be manufactured under the provisions of its original approval.

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 Class Delta-4 in RTCA, Inc. document RTCA/DO-229D, Change 1, *Minimum Operational Performance Standards for Global Positioning System/Satellite-Based Augmentation System Airborne Equipment* dated February 1, 2013, Section 2. Class Gamma and Class Delta-4 equipment are defined in

RTCA/DO-229D, Change 1, Section 1.4.

Class Delta-4 applicants have the option to use a TSO-C205 Delta-4 CCA functional sensor. Applicants choosing to use a TSO-C205 Delta-4 CCA can take certification compliance credit by virtue of the TSO-C205 TSOA for:

- Meeting the MPS section 2.1.1, 2.1.5, and 2.3 requirements;
- The hardware/software qualification;
- The failure condition classification; and,
- MPS section 2.5 performance testing (functional qualification) except those specified in Appendix 1 of this TSO.

The TSO-C146d, Class Delta-4 applicant using a TSO-C205 Delta CCA functional sensor shall perform the testing described in Appendix 1 and satisfy the remaining paragraphs in this TSO not covered by the bullets above to receive a TSO-C146d TSOA. The end-use manufacturer that uses a TSO-C205 Delta-4 CCA functional sensor as part of their TSO-C146d application assumes full responsibility for the design and function under their TSO-C146d authorization per 14 CFR § 21 Subpart O.

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 with Class Gamma, these TSO standards do not address integration issues with other avionics.

b. Failure Condition Classifications.

(1) Failure of the function defined in paragraph **3.a** resulting in misleading information for en route, terminal, approach lateral navigation (LNAV), and approach LNAV/vertical navigation (VNAV) navigation data is a *Major* failure condition,

(2) Failure of the function defined in paragraph **3.a** resulting in misleading information for approach localizer performance without vertical guidance (LP), and approach localizer performance with vertical guidance (LPV) navigation data is a *Hazardous* failure condition, and

(3) Loss of the function defined in paragraph **3.a** for en route through LP/LPV navigation data is a *Major* failure condition.

(4) Design the system to at least these failure condition classifications consistent with the operational capability.

c. **Functional Qualification.**

(1) Demonstrate the required functional performance under the test conditions specified in RTCA/DO-229D, Change 1, Section 2.5, or

(2) When using a TSO-C205 Delta CCA functional sensor, demonstrate the required performance under the test conditions in appendix 1 of this TSO.

d. **Environmental Qualification.** Demonstrate the required performance under the test conditions specified in RTCA/DO-229D, Change 1, Section 2.4 using standard environmental conditions and test procedures appropriate for airborne equipment. RTCA/DO-229D, Change 1 requires the use of 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. However, you may use a different standard environmental condition and test procedure than RTCA/DO-160E provided the standard is appropriate for the GNSS equipment.

Note 1: The use of RTCA/DO-160D (with Changes 1 and 2 only, incorporated) or earlier versions is generally not considered appropriate and will require substantiation via the deviation process as discussed in paragraph 3.g of this TSO.

Note 2: Applicants using a TSO-C205 Delta CCA must perform the environmental qualification with the Delta CCA in the end-use equipment.

e. **Software Qualification.** If the article includes software:

(1) Develop the software according to RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*, dated December 1, 1992 to at least the software level consistent with the failure condition classification defined in paragraph 3.b of this TSO, or

Note: The certification liaison process objectives will be considered satisfied after FAA review of the applicable life cycle data.

(2) Applicants using a TSO-C205 Delta CCA functional sensor may use TSO-C205 as substantiation for the software qualification.

f. **Electronic Hardware Qualification.** If the article includes complex custom airborne electronic hardware:

(1) Develop the component according to *RTCA, Inc. Document RTCA/DO-254, Design Assurance Guidance for Airborne Electronic Hardware* to at least the design assurance level consistent with the failure condition classification defined in paragraph 3.b of this TSO. For custom airborne electronic hardware determined to be simple, RTCA/DO-254, paragraph 1.6 applies, or

Note: The certification liaison process objectives will be considered satisfied after FAA review of the applicable life cycle data.

(2) Applicants using a TSO-C205 Delta CCA functional sensor may use TSO-C205 as substantiation for the hardware qualification.

g. Barometric-aided Fault Detection and Exclusion (FDE). If the equipment uses barometric-aiding to enhance FDE availability, then the equipment must meet the requirements in RTCA/DO-229D, Change 1, 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 the provision of 14 CFR § 21.618.

4. MARKING.

a. Mark at least one major component permanently and legibly with all the information in 14 CFR § 45.15(b). The marking must include the serial number.

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); and,

(2) Each subassembly of the article that you determined may be interchangeable.

c. If the article includes software and/or airborne electronic hardware, then the article part numbering scheme must identify the software and airborne electronic hardware configuration. The part numbering scheme can use separate, unique part numbers for software, hardware, and airborne electronic hardware.

d. You may use electronic part marking to identify software or airborne electronic hardware components by embedding the identification within the hardware component itself (using software) rather than marking it on the equipment nameplate. If electronic marking is used, it must be readily accessible without the use of special tools or equipment.

e. At least one major component must be permanently and legibly marked with the operational equipment class (for example, Class 2) as defined in RTCA/DO-229D, Change 1, 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, Change 1.

5. APPLICATION DATA REQUIREMENTS. You must give the FAA aircraft certification office (ACO) manager responsible for your facility a statement of conformance, as

specified in 14 CFR § 21.603(a)(1) and one copy each of the following technical data to support your design and production approval. LODA applicants must submit the same data (excluding paragraph 5.k) through their civil aviation authority.

a. A Manual(s) containing the following:

(1) Operating instructions and equipment limitations sufficient to describe the equipment's operational capability.

(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 on 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.

(4) Describe in detail any deviations.

(5) Installation procedures and limitations sufficient to ensure that the airborne navigation sensors, using GPS augmented by SBAS, when installed according to the installation or operational procedures, still meets this TSO's requirements. Limitations must identify any unique aspects of the installation. The limitations must include a note with the following statement:

“This article meets the minimum performance and quality control standards required by a technical standard order (TSO).
Installation of this article requires separate approval.”

(6) For each unique configuration of software and airborne electronic hardware, reference the following:

- (a) Software part number including revision and design assurance level;
- (b) Airborne electronic hardware part number including revision and design assurance level; and,
- (c) Functional description.

(7) A summary of the test conditions used for environmental qualifications for each component of the article. For example, a form as described in RTCA/DO-160E, *Environmental Conditions and Test Procedures for Airborne Equipment*, Appendix A.

(8) Schematic drawings, wiring diagrams, and any other documentation necessary for installation of the airborne navigation sensors, using GPS augmented by SBAS.

(9) List of major components, such as an antenna, by part number, that make up the airborne navigation sensors, using GPS augmented by SBAS complying with the standards prescribed under this TSO. Include vendor part number cross-references, when applicable.

(a) If the equipment can satisfy the requirements of RTCA/DO-229D, Change 1 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.

(b) If the equipment is installed with a standard antenna, include maximum tolerable currents and voltages into the antenna port. 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.

(10) List of replaceable components, by part number, that makes up the airborne navigation sensors, using GPS augmented by SBAS. Include vendor part number cross-references, when applicable.

b. Instructions covering periodic maintenance, calibration, and repair, for the continued airworthiness of airborne navigation sensors, using GPS augmented by SBAS. Include recommended inspection intervals and service life, as appropriate.

c. If not using a TSO-C205 Class Delta-4 functional sensor and the article includes software: a plan for software aspects of certification (PSAC), software configuration index, and software accomplishment summary.

d. If not using a TSO-C205 Class Delta-4 functional sensor and the article includes simple or complex custom airborne electronic hardware: a plan for hardware aspects of certification (PHAC), hardware verification plan, top-level drawing, and hardware accomplishment summary (or similar document, as applicable).

e. Nameplate drawing with the information required by paragraph **4** of this TSO.

f. A summary of the database updating process that meets the requirements in RTCA/DO-229D, Change 1 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.

g. Adequate specifics on the interface between the GPS/SBAS sensor and other systems to ensure proper functioning of the integrated system. If the equipment depends on any inputs (like baro-aided FDE) to satisfy the requirements of RTCA/DO-229D, Change 1, make those inputs a requirement in the installation. Include this requirement in the IM as a limitation.

h. 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 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.

i. 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.

j. Identify functionality or performance contained in the article not evaluated under paragraph **3** of this TSO (that is, non-TSO functions). Non-TSO functions are accepted in parallel with the TSO authorization. For those non-TSO functions to be accepted, you must declare these functions and include the following information with your TSO application:

(1) Description of the non-TSO function(s), such as performance specifications, failure condition classifications, software, hardware, and environmental qualification levels. Include a statement confirming that the non-TSO function(s) don't interfere with the article's compliance with the requirements of paragraph **3**.

(2) Installation procedures and limitations sufficient to ensure that the non-TSO function(s) meets the declared functions and performance specification(s) described in paragraph **5.j.(1)**.

(3) Instructions for continued performance applicable to the non-TSO function(s) described in paragraph **5.j.(1)**.

(4) Interface requirements and applicable installation test procedures to ensure compliance with the performance data defined in paragraph **5.j.(1)**.

(5) Test plans, analysis and results, as appropriate, to verify that performance of the hosting TSO article is not affected by the non-TSO function(s).

(6) Test plans, analysis and results, as appropriate, to verify the function and performance of the non-TSO function(s) as described in paragraph **5.j.(1)**.

k. The quality system description required by 14 CFR § 21.608, including functional test specifications. The quality system should ensure that you will detect any change to the approved design that could adversely affect compliance with the TSO MPS, and reject the article accordingly. (Not required for LODA applicants.)

l. Material and process specifications list.

m. List of all drawings and processes (including revision level) that define the article's design.

n. Manufacturer's TSO qualification report showing results of testing accomplished according to paragraph **3.c** of this TSO.

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

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

b. Equipment calibration procedures.

c. Schematic drawings.

d. Wiring diagrams.

e. Material and process specifications.

f. The results of the environmental qualification tests conducted according to paragraph **3.d** of this TSO.

g. If not using TSO-C205 and the article includes software, the appropriate documentation defined in RTCA/DO-178B including all data supporting the applicable objectives in Annex A, *Process Objectives and Outputs by Software Level*.

h. If not using TSO-C205 and the article includes complex custom airborne electronic hardware, the appropriate hardware life cycle data in combination with design assurance level, as defined in RTCA/DO-254, Appendix A, Table A-1. For simple custom airborne electronic hardware, the following data: test cases or procedures, test results, test coverage analysis, tool assessment and qualification data, and configuration management records, including problem reports.

i. If not using TSO-C205, all the data necessary to evaluate the geo stationary (GEO) satellite bias as defined in RTCA/DO-229D, Change 1, Section 2.1.4.1.5.

j. If the article contains non-TSO function(s), you must also make available items **6.a** through **6.h** as they pertain to the non-TSO function(s).

7. FURNISHED DATA REQUIREMENTS.

a. If furnishing one or more articles manufactured under this TSO to one entity (such as an operator or repair station), provide one copy or on-line access to the data in paragraphs **5.a**, **5.b**, and **5.g** through **5.i** of this TSO. Add any other data needed for the proper installation, certification, use, or for continued compliance with the TSO, of the airborne navigation sensors, using GPS augmented by SBAS.

b. If the article contains declared non-TSO function(s), include one copy of the data in paragraphs **5.j.(1)** through **5.j.(4)**.

8. HOW TO GET REFERENCED DOCUMENTS.

a. Order RTCA documents from RTCA Inc., 1150 18th Street NW, Suite 910, 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 parts 21 and 45 from the Superintendent of Documents, Government Printing Office, P.O. Box 979050, St. Louis, MO 63197. 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. END-USE EQUIPMENT MANUFACTURER TESTS FOR DELTA CCA FUNCTIONAL SENSORS USED FOR NAVIGATION APPLICATIONS

1. Scope.

This appendix describes the required supplementary equipment level testing, in addition to the environmental testing of RTCA/DO-229D, Change 1, section 2.4, required by the end-use equipment manufacturer to receive a TSO-C146d Class Delta-4 authorization when using a TSO-C205 Delta CCA functional sensor. These test procedures are intended to streamline and simplify the TSO-C146d authorization process for the end-use equipment manufacturer by allowing credit for the design and selected testing done at the Delta CCA functional sensor level. However, the end-use equipment manufacturer retains full responsibility for the design and control of the article per their TSO-C146d TSOA.

2. General Principles.

(a) Testing methods for GPS/SBAS equipment have been standardized by RTCA/DO-229D, Change 1 and serve as the basis for TSO-C146d. RTCA/DO-229D, Change 1 was written with the perspective of equipment that can be installed on aircraft. Section 2.4 specifically addresses the issues of the environment in which the equipment operates and provides approved test methods to validate performance in this environment. Section 2.4 represents RTCA consensus in identifying which RTCA/DO-229D, Change 1 requirements are sensitive to environmental effects. These requirements are listed in the environmental tables referenced in section 2.4.1.

(b) The determination that a MOPS requirement is susceptible to the environment does not depend on whether or not the implementation is a CCA within some host equipment. Only the sensitivity to environment is affected. This is the same concept as an equipment enclosure designed to protect against a benign environment compared to one designed for a severe environment; the identification of susceptible requirements is the same.

(c) Therefore this appendix uses the tables of RTCA/DO-229D, Change 1, section 2.4.1 to identify the MOPS requirements susceptible to environmental conditions for a Delta CCA functional sensor in the end-use equipment. The focus is on the change in environment seen by the Delta CCA functional sensor as a result of its installation in the end-use equipment. For example, other components inside the end-use equipment may radiate RF energy that could interfere with the GPS functions; therefore the ambient testing done at CCA level is not equivalent to tests done in the end-use equipment. This is the basis for defining the section 2.5 performance tests that need to be repeated by the end-use equipment manufacturer.

(d) The Class Delta-4 environmental table referenced in RTCA/DO-229D, Change 1, section 2.4.1 are the prime source to determine the MOPS performance requirements susceptible to environmental conditions. Based on the table, Class Delta-4 has the same susceptible requirements as Class Beta, but adds two additional requirements for navigation display and database that are optional capabilities for Class Delta-4. Those Delta-4 requirements similar to Class Beta can be grouped in two categories: those susceptible to most types of environmental conditions (described in section 3) and those susceptible to just a few (described in section 4).

(e) The options for database and navigation displays in Delta-4 equipment do not present any repeat MOPS testing requirements for the end-use manufacturer incorporating a TSO-C205 Delta CCA functional sensor. The environmental qualification performed by the end-use manufacturer according to TSO-C146d is sufficient. The rationale is stated below.

(1) The database requirement testing under environment is meant to assure that the database storage hardware, which may be separate, is fully functional during environment. As the pass criteria for such testing is that the retrieved data is correct, the test procedures under environment are as sensitive to hardware issues as any ambient environment test. Therefore nothing justifies repeating tests under ambient conditions in the end-use equipment.

(2) End-use equipment that includes a database must perform the environmental qualification specified by TSO-C146d and MOPS section 2.4 irrespective of whether the database is hosted in the Delta CCA functional sensor or elsewhere in the equipment.

(3) It is impossible for the Delta CCA functional sensor to incorporate a display or be a display.

3. Performance Requirements Susceptible to Most Environmental Conditions.

The RTCA/DO-229D, Change 1 requirements for Accuracy (2.1.5.1) and Sensitivity and Dynamic Range (2.1.1.10) are sensitive to most environmental conditions. However, these requirements are linked to the message loss rate requirement in 2.1.1.3.2. Section 3 identifies the testing end-use equipment manufacturers are required to repeat to demonstrate the Delta CCA functional sensor continues to meet the Accuracy, Dynamic Range, and Message Loss Rate performance requirements after installation in the end-use equipment. All tests will be run under conditions where the end-use equipment functions are fully enabled to create the worst-case environment.

3.1 RTCA/DO-229D, Change 1, 2.5.8 Accuracy Test.

(a) The accuracy test described in section 2.5.8 is actually a joint test covering both accuracy and sensitivity and dynamic range. This joint testing also applies under environment as stated in section 2.4.1.1.5 with environmental adaptation as described in section 2.4.1.1.1.

(b) The demonstration of accuracy is done in accordance with section 2.5.8.1 only for the test case with a broadband external interference noise. This test must be repeated when the CCA is installed in the end-use equipment and it is sufficient to perform it using broadband interference.

(1) The environmental testing is limited to broadband interference as it represents the worst case signal to noise condition which is the most sensitive to environmental effects. This applies equally to the environment for the CCA created by the end-use equipment.

(2) Section 2.5.8 contains a measurement accuracy test in 2.5.8.1 with the detailed test procedure in 2.5.8.2. The 2.5.8.1 test must be run under the worst case environment identified in the “Additional considerations for internal interference sources” section below.

The measurement accuracy testing can be combined with the message loss rate testing in 2.5.2.1.

(3) Section 2.5.8.3 is a 24-Hour actual satellite accuracy test. The section 2.5.8.3 test exposes the equipment to a variety of signal conditions and data processing conditions over varying satellite geometry that will increase confidence that no unforeseen interactions between components within the end-use equipment and the Delta CCA functional sensor goes undetected. The 24 hr testing in 2.5.8.3 can be combined with the 24 hr message loss rate testing in 2.5.2.4 (see Additional Considerations for Internal Interference Sources section).

(4) Section 2.5.8.4 (SBAS Tracking Bias) is an analysis of the GPS hardware and is therefore not necessary to repeat at the end-use equipment level as long as no extra RF components that affect the RF filtering response are inserted in the RF path. Otherwise the end-use equipment manufacturer must repeat the SBAS Tracking Bias test as well.

(c) The test threshold is relaxed from 110% to 125% as specified in table 2-25 of the 2.5.8.2.1 test procedure to shorten test time. However, Section 2.5.8 testing (excluding the SBAS Tracking Bias test in 2.5.8.4) for the CCA in the end-use equipment shall be under ambient conditions per section 2.5 with the 110% test pass threshold for maximum test sensitivity.

(d) The Section 2.5.8 testing (excluding the SBAS Tracking Bias test in 2.5.8.4) will be repeated against the accuracy requirement in section 2.1.5.1.

(e) Only the broadband external interference noise test case using minimum satellite power will be executed in most cases to shorten test time. Section 2.5.8.1 testing will be repeated for both minimum and maximum satellite power for the worst case environment only.

3.2 RTCA/DO-229D, Change 1, 2.5.2 Message Loss Rate Test.

(a) Section 2.5.2 specifies the message loss rate test for the 2.1.1.3.2 message loss rate requirement. This test is conducted in conjunction with the 2.5.8 accuracy testing. Section 2.5.2.2 defines the test procedure to collect data verifying the SBAS message loss rate in the presence of interference using the test cases where the SBAS satellite is at minimum power. Section 2.5.2.3 defines the pass/fail criteria.

(b) The test in section 2.5.2.2 will be performed during the measurement accuracy broadband interference test case described in paragraph 3.1.

(c) The test procedure in section 2.5.2.4.1 is run in conjunction with the 2.5.8.3 24-hour accuracy test. Section 2.5.2.4.2 defines the pass/fail criteria for the test case described in paragraph 3.1(b)(3).

4. Performance Requirements Partially Susceptible to Environmental Conditions.

(a) The class Delta-4 table 2-20 in section 2.4.1 of RTCA/DO-229D, Change 1 indicates the requirements for Acquisition Time (2.1.1.7) and Reacquisition Time (2.1.1.9) are sensitive to four environmental conditions: Icing, Lightning Induced Transient Susceptibility, Lightning Direct Effects, and Normal/Abnormal Operating Conditions. The requirements for Loss of Navigation (2.1.1.13.2, 2.1.5.12.2, and 2.3.6.2) are sensitive to low and high operating temperature.

Note: Class Delta-4 provides deviation guidance only during the final approach segment of an LP/LPV approach where loss of integrity is treated as a loss of navigation capability.

(b) The Lightning Induced Transient Susceptibility, Lightning Direct Effects, or Icing environmental conditions are not pertinent to the environment created by the end-use equipment relative to the Delta CCA functional sensor. However, the end-use equipment manufacturer remains responsible for meeting the overall environmental qualification at the end-use equipment level.

(c) Loss of navigation indications are limited to temperature testing and the information in RTCA/DO-229D, Change 1, sections 2.4.1.1.2 and 2.4.1.1.3 is appropriate. The purpose is to ensure that the interface used to indicate the loss of navigation is functional under environmental conditions after the Delta CCA functional sensor is installed in the end-use equipment. Sections 2.4.1.1.2 and 2.4.1.1.3 indicate that any source that generates the indication can be used since it is the interface and not the detection mechanism that is verified. The temperature testing done at the end-use equipment level is the worst-case scenario. It is not necessary to repeat the CCA level test at room temperature in the end-use equipment since the environmental qualification adequately addresses testing for these requirements.

Note: The Class Delta table requires more than just temperature testing under environment to support the optional display component of Class Delta. Since a CCA cannot be a display or incorporate a display, the additional testing under environment does not apply.

(d) RTCA/DO-160E section 16 relates to aircraft power supply (refer to TSO paragraph 3.d for environmental qualification requirements). Sections 16.5.1.2 and 16.6.1.2 are for Normal/Abnormal Operating Conditions. Given the potential susceptibility of the Delta CCA functional sensor to power supply noise, it is prudent to repeat tests at the end-use equipment level on this basis.

(e) Sections 4.1 and 4.2 identify the testing end-use equipment manufacturers are required to repeat to demonstrate the Delta CCA functional sensor continues to meet the Acquisition Time and Reacquisition Time performance requirements relative to Normal/Abnormal Operating Conditions after installation in the end-use equipment. All tests will be run under conditions where the end-use equipment functions are fully enabled to create the worst-case environment.

4.1 2.5.4 Initial Acquisition Test Procedures.

The information in RTCA/DO-229D, Change 1, section 2.4.1.1.4 on the initial acquisition test in section 2.5.4 applies. The end-use equipment manufacturer shall repeat the initial acquisition testing described in RTCA/DO-229D, Change 1, section 2.5.4.

4.2 2.5.6 Satellite Reacquisition Time Test.

The end-use equipment manufacturer is required to repeat the Satellite Reacquisition Time testing in RTCA/DO-229D, Change 1, section 2.5.6.

5. Additional Considerations for Internal Interference Sources.

(a) Installing a Delta CCA functional sensor into end-use equipment that also includes other functions requires careful evaluation of potential internal radiated and conducted interference. The end-use equipment manufacturer must evaluate each operating mode to determine if the mode changes the environment for the installed Delta CCA functional sensor. If there is only one environment or there is clearly one worst case environment, then the accuracy and message loss rate testing in section 3 can be run in that operating mode only. For example, if the end-use equipment includes an RF transmitter that radiates at one frequency; one could reasonably argue that setting the transmitter at full power with maximum data throughput will generate a clear worst-case environment in which to run all testing.

(b) In the case of multiple environments, the accuracy and message loss rate tests can either be run under each environment or the methodology in RTCA/DO-229D, Change 1, section 2.4.1.2.3 can be used to run an aggregate with approximately equal time in each mode. The methodology in section 2.4.1.2.3 must be used to identify modes of greatest susceptibility under which the combined accuracy and message loss rate are repeated in addition to the aggregate test. For example, the 2.4.1.2.3 methodology is appropriate for end-use equipment that contains a high power transmitter operating on a large number of frequencies such that it is impractical to run a test at each frequency. This is analogous to the large number of frequencies that need to be tested during RTCA/DO-160E RF and Induced Signal Susceptibility testing and is the reason why the section 2.4.1.2.3 methodology was developed.

(c) It is sufficient to identify one worst case environment when performing acquisition and 24 hour accuracy testing.

6. Summary.

(a) The end-use equipment manufacturer that incorporates a Delta CCA functional sensor is required to repeat the following RTCA/DO-229D, Change 1, section 2.5 testing under ambient conditions (see paragraph 5) after installing the Delta CCA functional sensor in the end-use equipment:

- The section 2.5.8 Accuracy (excluding the SBAS Tracking Bias test in 2.5.8.4) adapted per section 2.4.1.1.1 except that the 110% test pass threshold is used.

Note: Excluding the SBAS Tracking Bias test is acceptable, provided the end-use equipment does not insert in the RF signal path, components that affect the filtering response. Otherwise the end-use equipment manufacturer must repeat the SBAS Tracking Bias test as well.

- The section 2.5.2 Message Loss Rate Test.
- The section 2.5.4 Initial Acquisition Test.
- The section 2.5.6 Satellite Reacquisition Time Test.

(b) The end-use equipment manufacturer remains responsible for completing a full environmental qualification evaluation (see TSO paragraph 3.d) at the end-use equipment level. The end-use equipment manufacturer that incorporates a Delta CCA functional sensor is required to repeat Loss of Navigation indication as part of the environmental qualification according to RTCA/DO-229D, Change 1, sections 2.4.1.1.2 and 2.4.1.1.3.