Department of Transportation
Federal Aviation Administration
Aircraft Certification Service
Washington, DC

TSO-C129a

Date: 2/20/96

Technical Standard Order

Subject: TSO-C129a, AIRBORNE SUPPLEMENTAL NAVIGATION EQUIPMENT USING THE GLOBAL POSITIONING SYSTEM (GPS)

a. Applicability.

(1) Minimum Performance Standard. This technical standard order (TSO) prescribes the minimum performance standard that airborne supplemental area navigation equipment using global positioning system (GPS) must meet in order to be identified with the applicable TSO marking. Airborne supplemental area navigation equipment using GPS that are to be so identified and that are manufactured on or after the date of this TSO must meet the minimum performance standard of Section 2, RTCA, Inc. Document No. RTCA/DO-208, "Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)," dated July 1991.

(2) Equipment Classes. Equipment approved under this TSO shall be identified with the applicable equipment class as follows:

(i) Class A( ). Equipment incorporating both the GPS sensor and navigation capability. This equipment shall incorporate Receiver Autonomous Integrity Monitoring (RAIM) as defined by paragraph (a)(3)(xv) of this TSO.

1. Class A1. En route, terminal, and non-precision approach (except localizer, localizer directional aid (LDA), and simplified directional facility (SDF)) navigation capability.

2. Class A2. En route and terminal navigation capability only.

(ii) Class B( ). Equipment consisting of a GPS sensor that provides data to an integrated navigation system (i.e., flight management system, multi-sensor navigation system, etc.). The equipment consisting of a GPS sensor must meet all of the Class B( ) requirements specified in this TSO in order to be identified with a Class B( ) marking.

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1. Class B1. En route, terminal, and non-precision approach (except localizer, LDA, and SDF) capability. This equipment provides RAIM capability as specified in paragraph (a)(4)(vii) of this TSO.

2. Class B2. En route and terminal capability only. This equipment provides RAIM capability as specified in paragraph (a)(4)(vii) of this TSO.

3. Class B3. En route, terminal, and non-precision approach (except localizer, LDA, and SDF) capability. This equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to that provided by RAIM as specified in paragraph (a)(4)(vii) of this TSO.

4. Class B4. En route and terminal capability only. This equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to that provided by RAIM as specified in paragraph (a)(4)(vii) of this TSO.

NOTE 1: Limitations on equipment installations that require the integrated navigation system with which the GPS sensor is interfaced to provide a level of GPS integrity equivalent to that provided by RAIM should be included in the installation instructions.

NOTE 2: Systems utilizing VOR and/or DME for integrity monitoring may require modification in the future as changes to the National Airspace System occur.

(iii) Class C( ). Equipment consisting of a GPS sensor that provides data to an integrated navigation system (i.e., flight management system, multi-sensor navigation system, etc.) which provides enhanced guidance to an autopilot or flight director in order to reduce flight technical error. Class C equipment is limited to installations in aircraft approved under 14 CFR Part 121 or equivalent criteria. (It is intended that this class of equipment need not meet the display requirements applicable to the other equipment classes of this TSO.) The equipment consisting of a GPS sensor must meet all of the Class C( ) requirements specified in this TSO in order to be identified with a Class C( ) marking.

1. Class C1. En route, terminal, and non-precision approach (except localizer, LDA, and SDF) capability. This equipment provides RAIM capability as specified in paragraph (a)(5)(vii) of this TSO.

2. Class C2. En route and terminal capability only. This equipment provides RAIM capability as specified in paragraph (a)(5)(vii) of this TSO.

3. Class C3. En route, terminal, and non-precision approach (except localizer, LDA, and SDF) capability. This equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to that provided by RAIM as specified in paragraph (a)(5)(vii) of this TSO.

4. Class C4. En route and terminal capability only. This equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to that provided by RAIM as specified in paragraph (a)(5)(vii) of this TSO.

NOTE 1: Limitations on equipment installations that require the integrated navigation system with which the GPS sensor is interfaced to provide a level of GPS integrity equivalent to that provided by RAIM should be included in the installation instructions.

NOTE 2: Systems utilizing VOR and/or DME for integrity monitoring may require modification in the future as changes to the National Airspace System occur.

(3) Exceptions to RTCA/DO-208 for Class A( ) Equipment:

(i) Operation of Controls. Add the following requirement to paragraph 2.1.4. of RTCA/DO-208: Controls shall be designed to maximize operational suitability and minimize pilot workload. Reliance on pilot memory for operational procedures shall be minimized.

(ii) Accessibility of Controls. Add the following requirement to paragraph 2.1.5 of RTCA/DO-208: Controls that are normally adjusted in flight shall be readily accessible and properly labeled as to their function.

(iii) Sensor Interfaces. In lieu of paragraph 2.1.6 of RTCA/DO-208, substitute the following requirement: The interfaces with other aircraft equipment must be designed such that normal or abnormal RNAV equipment operation shall not adversely affect the operation of other equipment nor shall normal or abnormal operation of other equipment adversely affect the RNAV equipment operation.

(iv) Control/Display Readability. In lieu of paragraph 2.1.8 of RTCA/DO-208, substitute the following requirement: The equipment shall be designed so that all displays and controls shall be readable under all normal cockpit conditions and expected ambient light conditions (total darkness to bright reflected sunlight). All displays and controls shall be arranged to facilitate equipment usage.

NOTE: Limitations on equipment installations to ensure display readability should be included in the installation instructions.

(v) Maneuver Anticipation. Add the following requirement to paragraph 2.1.10 of RTCA/DO-208: For systems approved for non precision approaches (class A1 equipment), maneuver anticipation (turning prior to the “to” waypoint) shall not be implemented at the missed approach fix or the missed approach holding fix.

(vi) Update Rate. In lieu of paragraph 2.1.11 of RTCA/DO-208, substitute the following requirement: Navigation information used for display shall be updated at an interval of 1.0 second or less.

(vii) Numeric Display Information. In lieu of paragraph 2.2.1.1.1 of RTCA/DO-208, substitute the following requirement:

1. Equipment certified to class A2 shall continuously provide either a display or electrical output with the following requirements:

a. The display shall be as accurate as the resolution required for the displayed full scale range, referenced to a centered CDI display (see table in paragraph (a)(3)(viii)).

b. The equipment shall provide a numeric display or electrical output of cross-track deviation to at least ± 20 nm (left and right). A minimum resolution of 0.1 nm up to 9.9 nm and 1.0 nm beyond shall be provided. The display may be pilot selectable.

2. Equipment certified to class A1, shall, in addition to the requirements for class A2:

a. Provide a numeric (digital) display or electrical output of cross-track deviation to a resolution of 0.01 nm for deviations less than 1.0 nm.

b. Compute and display track angle error (TAE) to the nearest one degree. Track angle error is the difference between desired track and actual track (magnetic or true). In lieu of providing a numeric display of track angle error, non-numeric TAE may be displayed in conjunction with the non-numeric cross-track deviation, provided the display provides equivalent situational awareness.

NOTE 1: While the numeric display need not be located with the non-numeric cross-track display (subparagraph 2.2.1.1.2) or in the pilot's primary field of view, Flight Technical Error (FTE) can be reduced when the numeric display is integrated with the non-numeric display or is located within the pilot's primary field of view. Both digital cross track and track angle error have been shown to reduce FTE. This information should be displayed together (either within the CDU or remotely displayed near the non-numeric display) for better tracking performance.

NOTE 2: The use of non-numeric cross track data integrated with non-numeric track angle error data into one display may provide the optimum of situation and control information for the best overall tracking performance.

(viii) Non-Numeric Display Information. In lieu of paragraph 2.2.1.1.2 of RTCA/DO-208, substitute the following requirements:

1. The equipment shall continuously provide either a display or electrical output with the following requirements:

	En route	Terminal	Non-Precision Approach
Full-Scale Deflection (± nm)	5.0	1.0	0.3
Readability (Display only, nm)	≤1.0	≤0.1	≤0.03
Minimum Discernible Movement (Display only, nm)	≤0.1	≤0.01	≤0.01
Resolution of Electrical Output Percentage of Full Scale (±)	1%	1%	1%
Accuracy of Centered Display (± nm)	0.2	0.1	0.01
Linearity of Display or Electrical Output (±)	20%	20%	20%

2. The applicable non-numeric display information shall be automatically presented upon activation of the appropriate operating mode and the conditions outlined in paragraph (a)(3)(xii).

3. A means shall be provided for manual selection of the applicable display sensitivities in paragraph (a)(3)(viii)1. Additionally, the equipment shall display the non-numeric scale sensitivity, or provide an electrical output to display this information on an external display.

4. For Class A1 equipment, manual selection of a different scale sensitivity shall result in deselection of the approach mode. A proper indication must be provided.

5. In lieu of a linear lateral deviation scale for the final approach segment (final approach fix to missed approach point), an angular deviation display that emulates the nominal ILS localizer/MLS azimuth display resolution may be used, beginning with a full scale cross-track deflection of ±0.3 nm at the final approach fix decreasing to ±0.0576 nm (plus or minus 350 feet) at the runway threshold.

(ix) Waypoint Entry. In lieu of paragraphs 2.2.1.5 and 2.2.1.9 of RTCA/DO-208, substitute the following requirements:

1. Equipment certified to class A2 shall at least provide the capability to manually enter and display (prior to its utilization in the flight plan) the coordinates of a waypoint in terms of latitude and longitude with a resolution of 0.1 minute or better. If the equipment provides the ability to enter a waypoint as a range and bearing from another waypoint, the waypoint input resolution shall be 0.1 nm and 1 degree or better.

2. Equipment certified to class A1 shall at least provide the capability to manually enter and display (prior to its utilization in the flight plan) the coordinates of a waypoint in terms of latitude and longitude with a resolution of 0.01 minute or better. If the equipment provides the ability to enter a waypoint as a range and bearing from another waypoint, the waypoint input resolution shall be 0.1 nm and 0.1 degree or better.

(x) Waypoint Storage. In lieu of paragraph 2.2.1.6 of RTCA/DO-208, substitute the following requirements:

1. The equipment shall provide an appropriately updatable navigation data base containing at least the following location information in terms of latitude and longitude with a resolution of 0.01 minute or better for the area(s) in which IFR operations are to be approved: all airports, VORs (and VORTACs), NDBs, and all named waypoints and intersections shown on en route and terminal area charts, Standard Instrument Departures (SIDs) and Standard Terminal Arrival Routes (STARs).

NOTE: Manual entry/update of navigation data base data shall not be possible. (This requirement does not preclude the storage of “user defined data” within the equipment.)

2. Equipment certified to class A1, in addition to the requirements of paragraph (a)(3)(x)1, shall provide the following:

a. The equipment navigation data base shall also include all waypoints and intersections included in published non-precision instrument approach (except localizer, LDA, and SDF) procedures.

b. The equipment shall store all waypoints, intersections, and/or navigation aids and present them in the correct order for a selected approach as depicted on published non-precision instrument approach procedure charts. The sequence of waypoints shall consist of at least the following: selected Initial Approach Fix (IAF), intermediate approach fix(es) (when applicable), final approach fix, missed approach point, and missed approach holding point. For procedures with multiple IAFs, the system shall present all IAFs and provide the capability for pilot selection of the desired IAF. Selection of the desired IAF shall automatically insert the remaining waypoints in the approach procedure in the proper sequence.

c. Waypoints utilized as a final approach fix or missed approach point in a non-precision approach procedure shall be uniquely identified as such to provide proper approach mode operation.

d. Modification of data associated with published instrument approach procedures by the user shall not be possible.

e. Waypoint data utilized in non-precision approach procedures shall be in terms of latitude and longitude and cannot be designated in terms of bearing (radial) and distance to/from a reference location.

f. When in the approach mode, except for holding patterns and procedure turns, the equipment must establish the desired flight path in terms of the path between defined endpoints up to the missed approach point.

3. The equipment shall provide the capability for entering, storing, and designating as part of the active flight plan a minimum of 9 discrete waypoints (including the active waypoint). In addition, for class A1 equipment, it shall store and designate as part of the active flight plan the complete sequence of waypoints from the navigation data base necessary to complete the selected approach including the missed approach.

4. Waypoints shall be coded in the navigation data base to identify them as “fly by” (turn anticipation permitted) or “fly over” (turn anticipation not permitted) as required by the instrument approach procedure, SID, or STAR. Waypoints which define the missed approach point and missed approach holding point in instrument approach procedures shall be coded as “fly over”.

5. Navigation data bases shall meet the standards specified in sections 3, 4, and 5 of RTCA/DO-200, “Preparation, Verification and Distribution of User Selectable Navigation Data Bases” and sections 2 through 7 of RTCA/DO-201, “User Recommendations for Aeronautical Information Services.”

(xi) Waypoint or Leg Sequencing. Add the following requirement to paragraph 2.2.1.7 of RTCA/DO-208:

1. The equipment shall provide the capability to fly from the present position direct to any designated waypoint. Access to this feature shall be by means of a single action by the pilot. Selection of the desired “TO” waypoint may require additional actions.

2. The equipment shall provide the capability for accomplishment of holding patterns and procedure turns. Activation of this function shall at least:

a. Change automatic waypoint sequencing to manual.

b. Permit the pilot to readily designate a waypoint and select a desired course (by means of a numerical keypad entry, HSI course pointer, CDI omni-bearing selector, etc.) to or from the designated waypoint (TO/FROM mode operation is acceptable).

c. Retain all subsequent waypoints in the active flight plan in the same sequence.

d. Permit the pilot to readily return to automatic waypoint sequencing at any time prior to the designated fix (“TO” waypoint) and continue with the existing flight plan.

3. Class A1 equipment, unless incorporating or interfaced with an appropriate situational awareness display (i.e., an electronic map), shall be designed to prevent automatic waypoint sequencing from the missed approach waypoint to the missed approach

holding waypoint. Except for equipment with an approved electronic map display, course guidance shall display an extension of the inbound track and distance from the missed approach waypoint until manual selection of the next desired waypoint. Manual sequencing to the next waypoint after the MAP shall be accomplished by means of no more than two actions by the pilot (e.g., acknowledgment of next waypoint and activate DIRECT TO).

(xii) Approach Mode Selection and Sequencing. Add the following requirement to RTCA/DO-208:

1. For accomplishment of non-precision approaches, when an approach is included in the active flight plan, class A1 equipment shall provide the following:

a. At a radial distance of 30 nm from the destination airport (not distance along the flight plan route), the equipment shall immediately transition to terminal integrity performance as specified in Table 2-1 of RTCA/DO-208:

b. The equipment can enable the approach either manually or automatically.

i. If the approach is enabled manually, the equipment shall provide an approach enable alert at a radial distance of 30 nm from the destination airport. After display of this alert, a means shall be provided to enable the approach mode with a single action by the pilot. Concurrent with the approach enable alert, a suitable means to alert the pilot of the need to manually insert the barometric pressure setting shall be provided (unless the automatic altitude input utilizes barometric corrected altitude data).

ii. If the approach is enabled automatically, the equipment shall activate the approach mode prior to a distance of 3 nm inbound to the final approach fix. The approach should not be enabled automatically more than 30 nm from the destination airport. An indication that the approach has been enabled shall be provided. Concurrent with this indication, a suitable means to alert the pilot of the need to manually insert the barometric pressure setting shall be provided (unless the automatic altitude input utilizes barometric corrected altitude data).

c. When the approach is enabled (either manually or automatically), the equipment shall provide a smooth transition from 5 nm non-numeric display sensitivity to 1 nm sensitivity. No unique indication of the sensitivity change is required.

d. At a distance of 3 nm inbound to the final approach fix, the equipment shall provide an annunciation indicating an automatic non-numeric display sensitivity change will occur. If the approach was not previously enabled, the approach enable alert shall be repeated (manual systems only).

e. At a distance of 2 nm inbound to the final approach fix, if the approach has been enabled, the equipment shall automatically verify that satellite vehicle geometry will be suitable during the approach. This must be done using the RAIM prediction function defined in paragraph (a)(3)(xv)4a, including the FAF and the MAP. If the RAIM function is predicted to be available, the equipment shall switch to approach mode and:

i. Immediately transition from terminal integrity performance to approach integrity performance as specified in Table 2-1 of RTCA/DO-208.

ii. Provide a smooth transition from 1 nm non-numeric display sensitivity to 0.3 nm sensitivity at the final approach fix.

f. If the RAIM function is not predicted to be available during the approach, or if the approach has not been enabled at a distance of 2 nm inbound to the final approach fix, the equipment shall provide an indication that approach navigation is not provided. This indication must be sufficient to ensure that the pilot will not inadvertently conduct an approach using terminal area scale sensitivity.

2. If the pilot manually sequences to the missed approach holding point, the equipment shall:

a. Transition from approach integrity performance to terminal integrity performance as specified in Table 2-1 of RTCA/DO-208.

b. Provide a smooth transition from 0.3 nm non-numeric display sensitivity to 1 nm sensitivity.

3. A means shall be provided for deselection of the approach mode with a single action by the pilot, e.g. single button push. Deselection of the approach mode shall:

a. Transition from RNAV (non-precision) approach integrity performance to terminal integrity performance as specified in Table 2-1 of RTCA/DO-208.

b. Provide a smooth transition from 0.3 nm non-numeric display sensitivity to 1 nm sensitivity.

4. If the ability to perform DME arcs is provided, the equipment shall permit the pilot to readily accomplish such procedures in accordance with published non-precision approach procedures utilizing piloting techniques similar to those applicable to use of the reference DME facility.

(xiii) <u>Failure/Status Indications</u>. In lieu of paragraph 2.2.1.10 of RTCA/DO-208, substitute the following requirement: The equipment shall indicate, independent of any operator action, the following:

1. By means of a navigation warning flag on the navigation display:

a. The absence of power required for the navigation function.

b. Any probable equipment malfunction or failure affecting the navigation function.

c. Loss of navigation function.

d. For equipment certified to class A1, inadequate or invalid navigation data in the approach mode detected in accordance with RTCA DO-208 paragraph 2.2.1.13, Table 2-1, and paragraph (a)(3)(xv) of this TSO.

e. For equipment certified to class A1, loss of the RAIM detection function in the approach mode, after passing the final approach fix. However, the navigation warning flag may be delayed until the RAIM detection function is lost for more than 5 minutes.

2. By means of an appropriately located annunciator:

a. When RAIM is not available, inadequate navigation data due to poor space vehicle geometry such that the probability that navigation error exceeds the position integrity performance requirements in RTCA/DO-208 (Table 2-1) is greater than or equal to 0.05.

b. The RAIM function detects a position error that exceeds the GPS position integrity performance requirements in RTCA/DO-208 (Table 2-1).

c. Loss of the RAIM function. Display of the integrity annunciation may be delayed for a period of time consistent with the requirements of paragraph (a)(3)(xiv)2 of this TSO.

d. For equipment certified to class A1, the loss of the RAIM detection function in the approach mode at or before the final approach fix, including the predicted unavailability of RAIM as described in paragraph (a)(3)(xii)1.f.

e. For equipment certified to class A1, failure to enable the approach as described in paragraph (a)(3)(xii)1.d.

f. For equipment certified to class A1, when operating in the approach mode without RAIM and navigation performance is degraded because Horizontal Dilution of Precision (HDOP) exceeds 4.0.

3. Additional navigation data (such as distance to waypoint, time to waypoint, ground speed, etc.) shall be removed or flagged when the adequacy of navigation information upon which this data is based cannot be assured.

NOTE: Presentation of a failure/status annunciation does not require removal of navigation information from the navigation display. Consideration should be given to continued display of navigation information concurrent with the failure/status annunciation when conditions warrant.

NOTE: It is impractical for the operator to monitor, unaided, the changing parameters that affect accuracy. Therefore, the equipment should monitor those parameters for degraded performance that may result from propagation, reception, geometry, selective availability (SA) or other effects to the extent possible and be capable of automatic compensation, deselection, or manual deselection following annunciation of degraded performance consistent with paragraph (a)(3)(xiv) of this TSO.

4. Approach mode status/annunciations. Equipment certified to class A1 shall provide:

a. An annunciation, suitable indication or message that the approach mode is enabled.

b. An annunciation that the system is in the approach mode (RAIM in RNAV (non-precision) approach integrity performance and non-numeric display in approach sensitivity).

c. An annunciation of impending automatic non-numeric display sensitivity change to approach sensitivity.

d. An annunciation to alert the pilot of the need to manually insert the barometric pressure (unless automatic altitude input utilizing barometric corrected altitude data is available).

e. An annunciation to alert the pilot to enable the approach mode.

(xiv) Annunciation of Integrity Alarm.

1. Delete the second sentence of the opening paragraph 2.2.1.13.2 of RTCA/DO-208 and replace with: "A separate and distinctive indication shall be raised in each of the following two circumstances."

2. Add the following requirement to paragraph 2.2.1.13.2 of RTCA/DO-208: In order to minimize nuisance integrity alarms when system navigation accuracy is otherwise not in doubt, properly substantiated compensating features (such as clock coasting, inertial data, other sensors, etc.) may be incorporated into the system. The alarm under these conditions may be delayed for a period of time consistent with the worst cases of undetected clock drift or other failures that would cause the position error to exceed the accuracy required for that phase of flight. The applicant must develop appropriate test procedures to demonstrate the proposed compensating features provide the required level of navigation accuracy and integrity.

(xv) RAIM Implementation. Any algorithm which verifies the integrity of the position output using GPS measurements and barometric aiding is considered a RAIM algorithm. An algorithm which uses additional information (e.g., multi-sensor system) to verify the integrity of the position output may be acceptable as a RAIM-equivalent. Note that if RAIM is not incorporated in the GPS sensor, the sensor is only eligible for Class B3, B4, C3, and C4 certification. For sensors that provide RAIM, add the following requirements to paragraph 2.2.1.13.3 of RTCA/DO-208:

1. The RAIM function shall provide a worldwide availability of at least 95% given the optimal 21 GPS constellation (evaluated at a maximum resolution of 3 degrees in latitude, 180 nm in longitude, every 5 minutes). Barometric altitude aiding may be necessary to achieve this availability. RAIM-equivalent functions must also demonstrate an availability of at least 95%. If the equipment incorporates altitude aiding, appropriate requirements can be found in paragraph (a)(3)(xxi).

2. The RAIM function shall provide terminal integrity performance as specified in Table 2-1 of RTCA/DO-208 within 30 nm of the departure and destination points. In addition, approach mode (class A1 equipment) integrity performance shall be provided from 2 nm prior to the final approach fix to the missed approach point. En route integrity performance shall be provided during other conditions.

3. The equipment shall automatically select the RAIM integrity performance requirements applicable to phase of flight.

4. Equipment certified to class A1 shall provide a RAIM prediction function:

a. This function must automatically predict the availability of RAIM at the final approach fix and missed approach point of an active approach when 2 nm inbound to the final approach fix.

b. This function shall provide the pilot, upon request, a means to determine if RAIM will be available at the planned destination at the estimated time of arrival (ETA) (within at least $\pm$15 minutes computed and displayed in intervals of 5 minutes or less). Once complete almanac data has been received, this capability shall be available at any time after the destination point and estimated time of arrival at that point are established. The availability of corrected barometric altitude (either by automatic or manual altimeter setting input) may be assumed for this purpose. (For the purpose of this calculation an acceptable value of the standard deviation of pressure altitude error is 50 meters.) A means to manually identify a satellite that is expected to be unavailable at the destination (for scheduled maintenance as identified in an FAA Notice to Airmen) shall be provided. Identification of such a satellite for RAIM prediction purposes should not affect the satellite selection process or deselect that satellite from use in the navigation solution.

c. This function shall display, upon request, RAIM availability at the ETA and over an interval of at least $\pm$15 minutes computed in intervals of 5 minutes or less about the ETA.

5. The GPS equipment shall detect a pseudorange step error greater than 1000 meters, including steps which cause loss of lock for less than 10 seconds. A pseudorange step is defined to be a sudden change in the measured distance to a satellite. If a pseudorange step is detected for a satellite, that satellite shall be excluded from use in the navigation algorithm until its integrity can be verified through fault detection (RAIM). The manufacturer is free to choose any method to calculate the predicted pseudorange or to detect a step. However, any method used should properly take into account satellite movement and aircraft dynamics up to a groundspeed of 750 knots and accelerations up to 14.7 meters/second/second.

(xvi) <u>2D Accuracy Requirements (95 percent probability)</u>. In lieu of paragraph 2.2.2 of RTCA/DO-208, substitute the following requirement: The total of error contributions of the airborne equipment shall not exceed either error value listed in this paragraph. The reference spheroid shall use latitude/longitude values corresponding to the WGS-84 ellipsoid (see Appendix B of RTCA/DO-208). Since FTE factors are beyond the control of the equipment manufacturer or installer, these error sources are not included in this paragraph. The FAA has determined that equipment meeting the display characteristics requirements contained in this TSO provide for acceptable values of FTE when properly installed in an aircraft.

GPS RNAV 2D Accuracy Requirements
(95% Confidence)

Error Type	Oceanic (nm)	En Route (random or J/V routes) (nm)	Terminal (nm)	Non-Precision Approach (nm)
Position fixing error*	0.124	0.124	0.124	0.056
CDI Centering**	0.2	0.2	0.2	0.01

* Equipment error assumes an average HDOP of 1.5, GPS equipment waypoint input and output resolution of 0.01 minute for approach/0.1 minute otherwise. Position fixing errors are static values

** The maximum difference between the displayed cross-track deviation and the computed cross-track deviation.

(xvii) Sensitivity and Dynamic Range. Add the following requirements to paragraph 2.2.3.1 of RTCA/DO-208: Antenna elevation mask angles below 7.5 degrees may be utilized provided the applicant develops acceptable test conditions and supporting analysis to substantiate use of the desired mask angle.

(xviii) Dynamic Tracking. Add the following requirement to paragraph 2.2.3.4 of RTCA/DO-208: The equipment shall meet the applicable GPS position integrity performance requirements of Table 2-1 within the specified times stated in paragraphs a. and b.

(xix) (VNAV) Functional and Accuracy Requirements-Standard Conditions. Add the following requirement to paragraph 2.3 of RTCA/DO-208: If the vertical navigation (VNAV) option is provided by the equipment, the equipment must meet the requirements of paragraphs 2.3 and 2.5.3 of RTCA/DO-208.

(xx) Altitude Measurement Tests. In addition to RTCA/DO 208, the following requirements and tests apply to equipment which uses altitude-aiding. If alternative algorithms or test procedures are to be used, the manufacturer shall establish a set of tests acceptable to and approved by the cognizant Aircraft Certification Office and demonstrate equivalent performance with those tests.

1. "2.5.2.5.3.8. Tests to Verify that Altitude Measurement is Properly Incorporated."

a. As stated in paragraph 2.5.2.5.1, all tests described in paragraph 2.5.2.5 apply to GPS equipment that employs a snapshot-type RAIM integrity algorithm that uses pseudorange measurements from GPS satellites either singly or in conjunction with an altitude input. The following on-line tests shall be performed to verify that the altitude measurement is properly incorporated. Tests should start early enough for the receiver to settle before each of the specified test periods begins.

b. All tests shall be conducted using the Optimal 21 constellation as described in Appendix I of RTCA/DO-208 for July 1, 1990. Test times are with respect to the GPS epoch time described in the same appendix. Note that the angle from the vernal equinox to the Greenwich meridian at GPS time 0:00 on July 1, 1990 is 278.8°, which must be taken into account when determining the position of satellites in an earth-centered, earth-fixed coordinate system.

i. For equipment which uses pressure altitude with local barometric correction as an optional input for GPS navigation and RAIM, conduct static tests with initial conditions as follows:

Test No.	Location (Lat/Long)	Geometric Altitude (Feet)*	Integrity Alarm Limit (nm)	Initial Space Vehicle (SV) Pseudorange Error (Meters)**	Failed SV	Initial Altitude Error (Meters)***
1	42°N/87.5°W	18,000	2.0	SV12 & SV16: -33 SV14 & SV20: +33	SV3	-477
2	42°N/87.5°W	18,000	2.0	SV9, SV14 & SV20: +33 SV12, SV16: -33	SV3	0
3	34°N/118°W	10,000	1.0	SV5, SV10 & SV15: +33 SV7: -33	SV4	-290
4	34°N/118°W	10,000	1.0	SV5, SV10 & SV15: +33 SV7 & SV12: -33	SV4	0
5	33°N/97°W	1,000	0.3	SV3, SV10 & SV21: +33 SV5: -33	SV2	-34
6	33°N/97°W	1,000	0.3	SV3, SV10 & SV21: +33 SV5 & SV15: -33	SV2	0
7	30°N/90°W	200	0.3	SV5, SV10 & SV17: +33 SV12: -33	SV15	-12
8	30°N/90°W	200	0.3	SV5, SV10 & SV17: +33 SV7 & SV12: -33	SV15	0

* Geometric altitude is the highest above the surface of the WGS-84 ellipsoid at the present position (latitude and longitude).

** A positive SV error causes an observed pseudorange which is smaller than the actual distance from the receiver to the SV.

*** A positive altitude error causes a barometric altitude which is higher than the geometric altitude.

ii. For these tests, the receiver is fixed at the geometric location and altitude specified and the SVs change their orbital positions. The “Failed SV” for each test must not provide any signals to the receiver for the duration of the test. If an initial error is not specified for a space vehicle (SV) pseudorange measurement, the error for the test for those SVs should be set to zero.

iii. Data should be recorded for each test during the specified “Period of Test” to determine the time at which the RAIM integrity limit alarm is activated. For a successful test, this alarm must not occur during the time from the start of the test to the time identified as the “Earliest Alarm Time”, but must occur between the time identified as "Earliest Alarm Time" and the “Latest Alarm Time”. As shown below, a positive error rate in meters per minute is induced in either the identified SV pseudorange value or the barometric altimeter input beginning at the “Start Time of Ramp Error” and continuing throughout the test. The magnitude of the error rate is specified by the “Error Rate”.

Test No.	Period of Test	Error Source	Start Time of Ramp Error	Error Rate (Meters/Min.)*	Earliest Alarm Time	Latest Alarm Time
1	07:20 to 07:45	SV9	07:30	86.2	07:38:41	07:40:15
2	07:20 to 07:45	Altimeter	07:30	-275	07:35:35	07:36:31
3	01:35 to 01:55	SV12	01:42	135	01:51:02	01:52:12
4	01:35 to 01:55	Altimeter	01:42	200	01:50:18	01:53:13
5	00:40 to 00:55	SV15	00:43	26.6	00:51:08	00:52:38
6	00:40 to 00:55	Altimeter	00:43	50	00:48:36	00:51:17
7	02:45 to 03:05	SV7	02:52	19	02:59:56	03:02:02
8	02:45 to 03:05	Altimeter	02:52	37	03:01:05	03:03:44

* A positive SV error causes pseudorange which is smaller than the actual distance from the receiver to the SV. A positive altitude error causes a barometric altitude which is higher than the geometric altitude.

2. For Class A1, A2, B1, B2, C1, and C2 equipment, conduct the following tests with pressure altitude used as an input for GPS navigation and RAIM. For these tests, the GPS receiver should be simulated in motion, orbiting around the “Location” with the “Ground Speed” listed below for the test initial conditions. The receiver should be positioned at the appropriate geometric altitude with the specified pressure altitude input at the beginning of the test. These altitudes are either maintained or reduced as specified by the “Altitude Profile”. The geometric altitude and the pressure altitude input should begin to be reduced at the “Time of Top of Descent” and should be reduced to the specified altitude at the “Time of Bottom of Descent”. The initial conditions for these tests are as follows:

Test No.	Location (Lat/ Long)	Altitude Profile (Feet)	Time of Top of Descent	Time of Bottom of Descent	Integrity Alarm Limit (nm)	Failed SV	Initial SV Errors* (Meters)	Initial Pressure Altitude Error** (Meters)	Ground Speed (Knots)
1	42°N/ 87.5°W	Level at 500	NA	NA	1.0	SV3	SV14 & SV20: +33 SV12 & SV16: -33	+150	150
2	30°N/ 90°W	Level at 500	NA	NA	1.0	SV15	SV3, SV8 & SV21: +33 SV6 & SV10: -33	0	150
3	34°N/ 118°W	40,000 Descend to 18,000	01:42	01:52	1.0	SV17	SV5, SV10 & SV15: +33 SV7: -33	+150	150
4	34°N/ 118°W	40,000 Descend to 18,000	01:42	01:52	1.0	SV17	SV5, SV10 & SV15: +33 SV7 & SV12: -33	0	150
5	34°N/ 118°W	18,000 Descend to 6,000	02:33	02:43	1.0	SV4	SV12 & SV17: +33 SV7 & SV15: -33	-150	150
6	34°N/ 118°W	18,000 Descend to 6,000	02:33	02:43	1.0	SV4	SV5, SV12 & SV17: +33 SV7 & SV15: -33	0	150
7	33°N/ 97°W	6,000 Descend to 500	03:35	03:45	1.0	SV15	SV5, SV12 & SV20: +33 SV17: -33	-150	150

Test No.	Location (Lat/ Long)	Altitude Profile (Feet)	Time of Top of Descent	Time of Bottom of Descent	Integrity Alarm Limit (nm)	Failed SV	Initial SV Errors* (Meters)	Initial Pressure Altitude Error** (Meters)	Ground Speed (Knots)
8	33°N/ 97°W	6,000 Descend to 500	03:35	03:45	1.0	SV15	SV5, SV12 & SV20: +33 SV7 & SV17: -33	0	150
9	42°N/ 87.5°W	Level at 500	NA	NA	2.0	SV3	SV14 & SV20: +33 SV12 & SV16: -33	-150	150
10	42°N/ 87.5°W	Level at 500	NA	NA	2.0	SV3	SV9, SV14 & SV20: +33 SV12 & SV16: -33	0	150
11	33°N/ 97°W	40,000 Descend to 5,000	06:57	07:47	1.0	SV3	SV14 &SV20: +33 SV12 & SV16: -33	-150	600
12	33°N/ 97°W	40,000 Descend to 5,000	06:57	07:47	1.0	SV3	SV9, SV14 & SV20: +33 SV12 & SV16: -33	0	600
13	30°N/ 90°W	Level at 500	NA	NA	1.0	SV3	SV9, SV14 & SV20: +33 SV12 &SV16: -33	0	600
14	30°N/ 90°W	6,000 Descend to 500	07:25	07:47	2.0	SV3	SV14 & SV20: +33 SV12 & SV16: -33	+150	600

* A positive SV error causes a pseudorange which is smaller than the actual distance from the receiver to the SV.

** A positive altitude error causes a barometric altitude which is higher than the geometric altitude.

a. For these tests the SVs change their orbital positions and the identified "Failed SV" must not provide any signals to the receiver for the duration of the tests. If an initial error is not specified for a space vehicle(SV) pseudorange measurement, the error for the test for those SVs should be set to zero. Data should be recorded for each test during the specified "Period of Test" to determine the time at which the RAIM integrity limit alarm is activated. For a successful test, this alarm must not occur during the time from the start of the test to the time identified as the "Earliest Alarm Time", but must occur between the time identified as the "Earliest Alarm Time" and the "Latest Alarm Time". As shown below, a positive error rate in meters per minute is induced in either the identified SV pseudorange value or the pressure altitude input beginning at the "Start Time of Ramp Error" and continuing until the end of the test. The magnitude of the error rate is specified by the "Error Rate."

b. A positive SV error causes a pseudorange which is smaller than the actual distance from the receiver to the SV.

c. A positive altitude error causes a barometric altitude which is higher than the geometric altitude.

Test No.	Period of Test	Error Source	Start Time of Ramp Error	Error Rate (Meters /Min)	Earliest Alarm Time	Latest Alarm Time

Test No.	Period of Test	Error Source	Start Time of Ramp Error	Error Rate (Meters /Min)	Earliest Alarm Time	Latest Alarm Time
1	07:25 to 07:45	SV9	07:30	34.7	07:37:55	07:39:36
2	23:15 to 23:30	Pressure Altitude	23:18	50	23:25:21	23:28:09
3	01:35 to 01:55	SV12	01:42	100	01:52:01	01:53:34
4	01:35 to 01:55	Pressure Altitude	01:42	134	01:45:22	01:47:17
5	02:30 to 02:45	SV5	02:33	64.3	02:42:10	02:44:23
6	02:30 to 02:45	Pressure Altitude	02:33	126.5	02:37:36	02:39:22
7	03:30 to 03:50	SV7	03:35	34.8	03:43:36	03:46:17
8	03:30 to 03:50	Pressure Altitude	03:35	99.6	03:41:33	03:43:13
9	07:25 to 07:45	SV9	07:32	31.1	07:40:50	07:42:46
10	07:25 to 07:45	Pressure Altitude	07:32	90.5	07:41:16	07:43:53
11	06:55 to 07:25	SV9	06:57	22.7	07:11:28	07:15:13
12	06:55 to 07:25	Pressure Altitude	06:57	66.5	07:10:30	07:15:12
13	06:55 to 07:50	Pressure Altitude	07:05	41.5	07:30:36	07:40:30
14	06:55 to 07:50	SV9	07:25	32	07:35:01	07:37:52

3. For Class A1, A2, B1, B2, C1, and C2 equipment conduct the following tests with pressure altitude used as an input for GPS navigation and RAIM. For these tests, the GPS receiver should be simulated in motion from the “Initial Location” at the beginning of the test and should then move along a great circle route with the specified “Ground Speed” toward the “Final Location”. The receiver should be positioned at the appropriate geometric altitude with the specified pressure altitude input at the beginning of the test. These altitudes are either maintained or reduced as specified by the “Altitude Profile”. The geometric altitude and the pressure altitude input should begin to be reduced at the “Time of Top of Descent” and should be reduced to the specified altitude at the “Time of Bottom of Descent”. The initial conditions for these tests are as follows:

Test No.	Initial Location (Lat/Long)	Altitude Profile (Feet)	Time of Top of Descent	Time of Bottom of Descent	Integrity Alarm Limit (nm)	Failed SV	Initial SV Errors* (Meters)	Initial Altitude Error** (Meters)	Ground Speed (Knots)
1	34°N /118°W	40,000 Descend to 5,000	21:30	22:20	1.0	SV3	SV6, SV10 & SV21: +33 SV8: -33	+150	600
2	34°N /118°W	40,000 Descend to 5,000	21:30	22:20	1.0	SV3	SV6, SV10 & SV21: +33 SV8 & SV13: -33	0	600
3	34°N /118°W	Level at 500	NA	NA	1.0	SV3	SV6, SV10 & SV21: +33 SV8 & SV13: -33	0	600
4	34°N /118°W	6,000 Descend to 500	22:15	22:55	2.0	SV3	SV6, SV10 & SV21: +33 SV8: -33	+150	600

* A positive SV error causes a pseudorange which is smaller than the actual distance from the receiver to the SV.

** A positive altitude error causes a barometric altitude which is higher than the geometric altitude.

a. For these tests the SVs change their orbital positions and the identified "Failed SV" must not provide any signals to the receiver for the duration of the tests. If an initial error is not specified for a space vehicle (SV) pseudorange measurement, the error for the test for those SVs should be set to zero. Data should be recorded for each test during the specified "Period of Test" to determine the time at which the RAIM integrity limit alarm is activated. For a successful test, this alarm must not occur during the time from the start of the test to the time identified as the "Earliest Alarm Time", but must occur between the time identified as the "Earliest Alarm Time" and the "Latest Alarm Time". As shown below a positive error rate in meters per minute is induced in either the identified SV pseudorange value or the pressure altitude input beginning at the "Start Time of Ramp Error" and continuing until the end of the test. The magnitude of the error rate is specified by the "Error Rate".

Test No.	Period of Test	Error Source	Start Time of Ramp Error	Error Rate (Meters/Min)	Earliest Alarm Time	Latest Alarm Time	Final Position (Lat/Long)
1	21:05 to 22:43	SV13	22:12	30	22:31:10	22:38:57	33°N/ 97°W
2	21:05 to 22:44	Altimeter	22:12	72	22:31:07	22:35:31	33°N/ 97°W
3	21:20 to 22:59	Altimeter	22:10	40	22:38:12	22:55:56	33°N/ 97°W
4	21:20 to 22:57	SV13	22:22	27	22:35:25	22:43:17	33°N/ 97°W

NOTE 1: All tests in Section 2.5.2.5.3.8 apply to RAIM algorithms that incorporate the altitude measurement as described in Section (a)(3)(xxi). For the tests of RAIM with altitude data calibrated by GPS, if 6 satellites are usable at the time of calibration, then calibration is done as described in paragraph (a)(3)(xxi) using all 6 satellites and not just 5 out of the 6.

NOTE 2: This testing requirement does not preclude the use of alternative RAIM algorithms. If alternative RAIM algorithms are used, or if the same RAIM algorithm is used but tracks only 5 satellites, then the manufacturer shall establish a set of tests acceptable to and approved by the cognizant Aircraft Certification Office and demonstrate equivalent performance with those tests.

(xxi) <u>Pressure Altitude Input Requirements</u>. If the equipment incorporates altitude aiding, the following requirements apply. An alternate acceptable algorithm for incorporating barometric altitude is specified in appendix G of RTCA/DO-229, "MOPS for GPS/Wide Area Augmentation System Airborne Equipment", January 16, 1996.

1. The equipment shall include a provision for automatic input of pressure altitude data. Pressure altitude shall be corrected/calibrated using GPS derived altitude data when and only when the maximum subset VDOP (VDOP max as defined below) is ≤ 5 and the test statistic S as defined in Equation 4 of Appendix F of RTCA/DO-208 is less than a threshold that corresponds to the 95th percentile point of the distribution of the test statistic in the presence of SA and given that no other errors are present. For example, in case of 5 satellites being used, the threshold is $3.841 \times (33.3)^2$ (from chi-square distribution table). These data shall be properly scaled to ensure the position accuracy is not degraded below that provided by GPS alone. An acceptable methodology of scaling is contained in this paragraph. Scaled altitude data shall be utilized in the navigation and RAIM detection functions when and only when these

functions cannot be provided by GPS alone. This requirement does not preclude the use of altitude data for smoothing.

NOTE: All equipment must be designed to automatically input at least pressure altitude data. As an option, the manufacturer may design a system which will accept an automatic input of pressure altitude corrected for the local barometric pressure setting applied by the aircraft's air data system in response to the pilot's action of setting the altimeter. Above a geometric altitude of 18,000 feet, equipment which uses pressure altitude corrected for the local barometric pressure setting shall treat this input as pressure altitude. Pressure is to be calibrated with GPS; this calibrated value is defined as the current value of pressure altitude minus the difference between the pressure altitude and GPS estimate of vertical position as determined at the most recent time when the calibration was accomplished. At and below a geometric altitude of 18,000 feet, equipment which uses pressure altitude corrected for the local barometric pressure setting as an input shall correct this measurement with the difference between the WGS-84 ellipsoid altitude and mean sea level altitude at the current latitude and longitude. A table which stores the values of this difference for each area of the WGS-84 ellipsoid bounded by 10° of latitude and longitude has been found to have sufficient resolution.

2. An alternate methodology for incorporation of pressure altitude data may be utilized, provided it yields at least equivalent performance. Use of alternate methods will require the manufacturer to conduct a statistical demonstration of its validity acceptable to and approved by the FAA. The ACO will review the test procedures and results prior to issuing a TSOA.

3. Additionally, Class A1 equipment, when operating in approach mode, shall provide the capability for manual input of barometric pressure setting (unless the automatic altitude input utilizes barometric corrected altitude data). Concurrent with the approach enable alert, a suitable means to alert the pilot of the need to manually insert the barometric pressure setting shall be provided if the setting is input manually. If the automatic altitude input utilizes barometric corrected altitude data, a means shall be provided for the pilot to confirm the automatic entry.

4. Two different ways of augmenting the GPS solution equation with altitude aiding are used. One is to use pressure altitude data calibrated with GPS derived altitude data. The other method is to use pressure altitude data corrected for the local barometric pressure setting and the difference between the WGS-84 ellipsoid altitude and mean sea level altitude at the present position.

5. Altitude data is used to modify matrix H in equation 1 of Appendix F of RTCA/DO-208 with the addition of the term s_{sv}/s_{baro} by adding an n+1 row with all 0 elements and s_{sv}/s_{baro} as the element in the third column.

$$H' = \begin{bmatrix} e_{11} & e_{12} & e_{13} & 1 \\ e_{21} & e_{22} & e_{23} & 1 \\ .. & .. & .. & .. \\ e_{n1} & e_{n2} & e_{n3} & 1 \\ 0 & 0 & s_{sv}/s_{baro} & 0 \end{bmatrix}$$

6. In a similar manner, the vector Z in equation 1 is modified by the addition of an n+1 element equal to $B/(s_{baro}/s_{sv})$.

$$Z' = \begin{bmatrix} Z \\ \\ B/(s_{baro}/s_{sv}) \end{bmatrix}$$

Where:

n = Number of satellites in use.
B = Difference between measured altitude (calibrated with GPS) and the estimated vertical position, when using pressure altitude.

or,

B = Difference between measured altitude [corrected for the difference between the GPS ellipsoid and the mean sea level altitude at the current position (an area bounded by 10 degrees of latitude and longitude has been found acceptable)] and the estimated vertical position, when using pressure altitude corrected with local barometric pressure setting at and below altitude of 18,000 ft.

s_{sv} (standard deviation of range error of satellite vehicle) = 33.3 meters

s_{baro} = standard deviation of pressure altitude error

Geometric Altitude (ft.)	s_{baro} (meters)
18,000	477
10,000	290
5,000	165
1,000	34
500	19
200	12

when using pressure altitude corrected with local barometric pressure setting at 18,000 ft. and below, or,

s_{baro} = RSS combination of e_c, b_{el} * v * t, and b_{en} when using pressure altitude calibrated by GPS.

e_c = $VDOP_{max}$ * s_{sv}; e_c is calculated at the time of most recent calibration

$VDOP_{max}$ = the maximum value of $VDOP_i$ for each satellite in use

$VDOP_i$ = VDOP with i^{th} satellite removed

b_{el} = 0.5 meters/nm when in level flight

b_{en} = 13 meters/1000 ft. altitude change above 18,000 ft. plus
23 meters/1000 ft. altitude change from 6000 to 18,000 ft. plus
32.5 meters/1000 ft. altitude change below 6000 ft.

v = average ground speed in knots since the last GPS calibration of altitude

t = flight time in hours since the last GPS calibration of altitude

NOTE: Average ground speed must be determined as the integral of instantaneous ground speed over the time since the last GPS calibration divided by the time since last GPS calibration. The tests of paragraph (a)(3)(xx)(1)(b) will be unsatisfactory if ground speed is determined by dividing the difference in position by time.

(xxii) Flight Plan Capability. Add the following requirement to RTCA/DO-208: The equipment shall provide the capability to create, display, and edit a flight plan consisting of a minimum of 9 waypoints. A means shall be provided to readily display each waypoint, individually or together, of the active flight plan (in sequence) for review.

(4) Exceptions to RTCA/DO-208 for Class B( ) Equipment:

(i) The following paragraphs of RTCA/DO-208 do not apply to GPS sensors certified to class B( ) requirements: 2.1.8, 2.1.10, 2.1.11, 2.2.1.1 through 2.2.1.10, 2.2.1.12, 2.3, 2.5.2.1 through 2.5.2.4, 2.5.2.10, and 2.5.3. The following paragraphs of RTCA/DO-208 do not apply to GPS sensors certified to class B(3) and Class B(4) requirements: 2.5.2.5 and 2.5.2.7. The integrated navigation system with which the GPS sensor is installed shall provide the following. GPS sensors certified to Class B( ) must demonstrate that the GPS sensor, when incorporated into an integrated navigation system (flight management system, multi-sensor navigation system, etc.) meets all of the requirements of this TSO, including the requirements listed below. The GPS installation procedures shall specify for reference which integrated navigation system was used for this demonstration.

1. Maneuver anticipation capability equivalent to that required by paragraph (a)(3)(v) of this TSO for equipment certified to class B1/B3.

2. Numeric display information equivalent to that required by paragraph (a)(3)(vii) of this TSO for the appropriate equipment class (B1/B3 or B2/B4).

3. Non-numeric display information equivalent to that required by paragraph (a)(3)(viii) of this TSO for the appropriate equipment class (B1/B3 or B2/B4).

4. Waypoint distance display capability equivalent to that required by RTCA/DO-208 paragraph 2.2.1.2 for the appropriate equipment class (B1/B3 or B2/B4).

5. TO-FROM Indication capability equivalent to that required by RTCA/DO-208 paragraph 2.2.1.3 for the appropriate equipment class (B1/B3 or B2/B4).

6. Flight path selection capability equivalent to that required by RTCA/DO-208 paragraph 2.2.1.4 for the appropriate equipment class (B1/B3 or B2/B4).

7. Waypoint entry and storage capability equivalent to that required by paragraphs (a)(3)(ix) and (x) of this TSO for the appropriate equipment class (B1/B3 or B2/B4).

8. Waypoint or leg sequencing capability equivalent to that required by paragraph (a)(3)(xi) of this TSO for the appropriate equipment class (B1/B3 or B2/B4).

9. Position display capability equivalent to that required by RTCA/DO-208 paragraph 2.2.1.8 for the appropriate equipment class (B1/B3 or B2/B4).

10. Failure/status indication capability equivalent to that required by paragraph (a)(3)(xiii) of this TSO for the appropriate equipment class (B1/B3 or B2/B4).

11. Flight plan capability equivalent to that required by paragraph (a)(3)(xxii) of this TSO for the appropriate equipment class (B1/B3 or B2/B4).

12. Approach mode sequencing capability equivalent to that required by paragraph (a)(3)(xii) of this TSO for the appropriate equipment class (B1/B3).

(ii) Operation of Controls. Add the following requirement to paragraph 2.1.4 of RTCA/DO-208: Controls shall be designed to maximize operational suitability and minimize pilot workload. Reliance on pilot memory for operational procedures shall be minimized.

(iii) Accessibility of Controls. Add the following requirement to paragraph 2.1.5 of RTCA/DO-208: Controls that are normally adjusted in flight shall be readily accessible and properly labeled as to their function.

(iv) Sensor Interfaces. In lieu of paragraph 2.1.6 of RTCA/DO-208, substitute the following requirement: The interfaces with other aircraft equipment must be designed such that normal or abnormal RNAV equipment operation shall not adversely affect the operation of other equipment nor shall normal or abnormal operation of other equipment adversely affect the RNAV equipment operation.

(v) Update Rate. In lieu of paragraph 2.1.11 of RTCA/DO-208, substitute the following requirement: Data output shall be updated at an interval of 1.0 second or less.

(vi) Integrity Alarm for GPS Receivers. Add the following requirements to paragraph 2.2.1.13 of RTCA/DO-208:

1. The requirements of this paragraph do not apply to equipment certified to class B3 and B4.

2. Delete the second sentence of the opening paragraph 2.2.1.13.2 and replace with: "A separate and distinctive indication shall be raised in each of the following two circumstances."

3. Add the following requirement to paragraph 2.2.1.13.2 of RTCA/DO-208: In order to minimize nuisance integrity alarms when system navigation accuracy is otherwise not in doubt, properly substantiated compensating features (such as clock coasting, pressure altitude, inertial data, other sensors, etc.) may be incorporated into the system. The alarm under these conditions may be delayed for a period of time consistent with the worst cases of undetected clock drift or other failures that would cause the position error to exceed the accuracy required for that phase of flight. The applicant must develop appropriate test procedures to demonstrate the proposed compensating features provide the required level of navigation accuracy and integrity.

(vii) RAIM Implementation. Any algorithm which verifies the integrity of the position output using GPS measurements and barometric aiding is considered a RAIM algorithm. An algorithm which uses additional information (e.g., multi-sensor system) to verify the integrity of the position output may be acceptable as a RAIM-equivalent. Note that if RAIM is not incorporated in the GPS sensor, the sensor is only eligible for Class B3, B4, C3, and C4 certification. For sensors that provide RAIM, add the following requirement to paragraph 2.2.1.13.3 of RTCA/DO-208:

1. The requirements of this paragraph do not apply to equipment certified to class B3 and B4.

2. The RAIM function shall provide a worldwide availability of at least 95% given the optimal 21 GPS constellation (evaluated at a maximum resolution of 3 degrees in latitude, 180 nm in longitude, every 5 minutes). Barometric altitude aiding may be necessary to achieve this availability. RAIM-equivalent functions must also demonstrate an availability of at least 95%. If the equipment incorporates altitude aiding, appropriate requirements can be found in paragraph (a)(4)(xi) of this TSO.

3. The integrated navigation system with which the GPS sensor is interfaced must provide the RAIM function with terminal integrity performance as specified in Table 2-1 of RTCA/DO-208 within 30 nm of the departure and destination points. In addition, approach mode (class B1 equipment) integrity performance shall be provided from 2 nm prior to the final approach fix to the missed approach point. En route integrity performance shall be provided during other conditions.

4. The equipment shall automatically select the RAIM integrity performance requirements applicable to the phase of flight.

5. Equipment certified to class B1 shall provide a RAIM prediction function:

a. This function must automatically predict the availability of RAIM at the final approach fix and missed approach point of an active approach when 2 nm inbound to the final approach fix.

b. This function shall provide the pilot, upon request, a means to determine if RAIM will be available at the planned destination at the estimated time of arrival (ETA) (within at least ±15 minutes computed and displayed in intervals of 5 minutes or less). Once complete almanac data has been received, this capability shall be available at any time after the destination point and estimated time of arrival at that point are established. The availability of corrected barometric altitude (either by automatic or manual altimeter setting input) may be assumed for this purpose. (For the purposes of this calculation, an acceptable value of s_{baro} is 50 meters.) A means to manually identify a satellite that is expected to be unavailable (for scheduled maintenance as identified in an FAA Notice to Airmen) shall be provided. Identification of such a satellite for RAIM prediction purposes should not affect the satellite selection process or deselect that satellite from use in the navigation solution.

c. This function shall display, upon request, RAIM availability at the ETA and over an interval of at least ±15 minutes computed in intervals of 5 minutes or less about the ETA.

6. The GPS equipment shall detect a pseudorange step error greater than 1000 meters, including steps which cause loss of lock for less than 10 seconds. A pseudorange step is defined to be a sudden change in the measured distance to a satellite. If a pseudorange step is detected for a satellite, that satellite shall be excluded from use in the navigation algorithm until its integrity can be verified through fault detection (RAIM). The manufacturer is free to choose any method to calculate the predicted pseudorange or to detect a step. However, any method used should properly take into account satellite movement and aircraft dynamics up to a groundspeed of 750 knots and accelerations up to 14.7 meters/second/second.

(viii) <u>2D Accuracy Requirements (95 percent probability)</u>. In lieu of paragraph 2.2.2 of RTCA/DO-208, substitute the following requirement: The total of error contributions of the airborne equipment shall not exceed the error value listed in this paragraph. The reference spheroid shall use latitude/longitude values corresponding to the WGS-84 ellipsoid (see Appendix B of RTCA/DO-208). Since FTE factors are beyond the control of the equipment manufacturer or installer, these error sources are not included in this paragraph.

GPS RNAV 2D Accuracy Requirements
(95% Confidence)

Error Type	Oceanic (nm)	En Route (random or J/V routes) (nm)	Terminal (nm)	Non-Precision Approach (nm)
Position fixing error*	0.124	0.124	0.124	0.056

* Equipment error assumes an average HDOP of 1.5, GPS equipment waypoint input and output resolution of 0.01 minute for approach/0.1 minute otherwise. Position fixing errors are static values.

(ix) Sensitivity and Dynamic Range. Add the following requirements to paragraph 2.2.3.1 of RTCA/DO-208: Antenna elevation mask angles below 7.5 degrees may be utilized provided the applicant develops acceptable test conditions and supporting analysis to substantiate use of the desired mask angle.

(x) Dynamic Tracking. Add the following requirement to paragraph 2.2.3.4 of RTCA/DO-208: The equipment shall meet the applicable GPS position integrity performance requirements of Table 2-1 within the specified times stated in paragraphs a. and b.

(xi) Pressure Altitude Input Requirements. If the equipment incorporates altitude aiding, the following requirements apply:

1. Pressure altitude data shall not be utilized in GPS sensors certified to class B3 and B4 for RAIM or position determination functions. This requirement does not preclude the use of altitude data for smoothing.

2. Equipment certified to class B1 and B2 shall utilize pressure altitude data in the same manner as described in paragraphs (a)(3)(xx) and (xxi) of this TSO.

(xii) Equipment Test Procedures. Add the following requirement to paragraph 2.5.2 of RTCA/DO-208: For equipment certified to class B3 and B4, paragraphs 2.5.2.5.1 through 2.5.2.5.3.7 do not apply.

(xiii) 2D Functional Performance. In lieu of paragraph 2.5.2.1 of RTCA/DO-208, substitute the following requirement: Each of the functional capabilities identified in subparagraph 2.2.1.11 shall be demonstrated. These capabilities shall be evaluated either by inspection or in conjunction with the tests described in paragraph 2.5.2.

(xiv) 2D Failure Indication. In lieu of paragraph 2.5.2.7 of RTCA/DO-208, substitute the following requirements:

1. Connect the equipment as shown in RTCA/DO-208, Figure 2-2. Remove the electrical power input to the equipment. There shall be a warning indication by the equipment.

2. The tests for the integrity of the navigation signals are specified in subparagraph 2.5.2.5 of RTCA/DO-208. For equipment certified to class B3 and B4, the requirements of this paragraph do not apply.

NOTE: These tests do not need to be performed for functions not incorporated in the equipment.

(5) Exceptions to RTCA/DO-208 for Class C( ) Equipment:

(i) The following paragraphs of RTCA/DO-208 do not apply to GPS sensors certified to class C( ) requirements: 2.1.8, 2.1.10, 2.1.11, 2.2.1.1 through 2.2.1.10, 2.2.1.12, 2.3, 2.5.2.1 through 2.5.2.4, 2.5.2.10, and 2.5.3. The following paragraphs of RTCA/DO-208 do not apply to GPS sensors certified to class C(3) and C(4) requirements: 2.5.2.5 and 2.5.2.7. The integrated navigation system with which the GPS sensor is installed shall provide the following: GPS sensors certified to Class C( ) must demonstrate that the GPS sensor, when incorporated into an integrated navigation system (flight management system, multi-sensor navigation system, etc.) meets all of the requirements of this TSO, including the requirements listed below. The GPS installation procedures shall specify for reference which integrated navigation system was used for this demonstration.

1. Maneuver anticipation capability equivalent to that required by paragraph (a)(3)(v) of this TSO for equipment certified to class C1/C3.

2. Waypoint distance display capability equivalent to that required by RTCA/DO-208 paragraph 2.2.1.2 for the appropriate equipment class (C1/C3 or C2/C4).

3. TO-FROM Indication capability equivalent to that required by RTCA/DO-208 paragraph 2.2.1.3 for the appropriate equipment class (C1/C3 or C2/C4).

4. Flight path selection capability equivalent to that required by RTCA/DO-208 paragraph 2.2.1.4 for the appropriate equipment class (C1/C3 or C3/C4).

5. Waypoint entry and storage capability equivalent to that required by paragraph (a)(3)(ix) and (a)(3)(x) of this TSO for the appropriate equipment class (C1/C3 or C2/C4).

6. Waypoint or leg sequencing capability equivalent to that required by paragraph (a)(3)(xi) of this TSO for the appropriate equipment class (C1/C3 or C2/C4).

7. Position display capability equivalent to that required by RTCA/DO-208 paragraph 2.2.1.8 for the appropriate equipment class (C1/C3 or C2/C4).

8. Failure/status indication capability equivalent to that required by paragraphs (a)(3)(xiii) 1., 2., and 3. of this TSO for the appropriate equipment class (C1/C3 or C2/C4).

9. Flight plan capability equivalent to that required by paragraph (a)(3)(xxii) of this TSO for the appropriate equipment class (C1/C3 or C2/C4).

10. Approach Mode Sequencing capability equivalent to that required by paragraph (a)(3)(xii) of this TSO for the appropriate equipment class (C1/C3), with the exception of paragraphs (a)(3)(xii)1c, (a)(3)(xii)1d, (a)(3)(xii)1e.ii, and (a)(3)(xii)2b, and (a)(3)(xii)3b.

(ii) Operation of Controls. Add the following requirement to paragraph 2.1.4. of RTCA/DO-208: Controls shall be designed to maximize operational suitability and minimize pilot workload. Reliance on pilot memory for operational procedures shall be minimized.

(iii) Accessibility of Controls. Add the following requirement to paragraph 2.1.5 of RTCA/DO-208: Controls that are normally adjusted in flight shall be readily accessible and properly labeled as to their function.

(iv) Sensor Interfaces. In lieu of paragraph 2.1.6 of RTCA/DO-208, substitute the following requirement: The interfaces with other aircraft equipment must be designed such that normal or abnormal RNAV equipment operation shall not adversely affect the operation of other equipment nor shall normal or abnormal operation of other equipment adversely affect the RNAV equipment operation.

(v) Update Rate. In lieu of paragraph 2.1.11 of RTCA/DO-208, substitute the following requirement: Data output shall be updated at an interval of 1.0 second or less.

(vi) Integrity Alarm for GPS Receivers. Add the following requirements to paragraph 2.2.1.13 of RTCA/DO-208:

1. The requirements of this paragraph do not apply to equipment certified to class C3 and C4.

2. Delete the second sentence of the opening paragraph 2.2.1.13.2 and replace with: “A separate and distinctive indication shall be raised in each of the following two circumstances.”

3. Add the following requirement to paragraph 2.2.1.13.2 of RTCA/DO-208: In order to minimize nuisance integrity alarms when system navigation accuracy is otherwise not in doubt, properly substantiated compensating features (such as clock coasting, pressure altitude, inertial data, other sensors, etc.) may be incorporated into the system.

The alarm under these conditions may be delayed for a period of time consistent with the worst cases of undetected clock drift or other failures that would cause the position error to exceed the accuracy required for that phase of flight. The applicant must develop appropriate test procedures to demonstrate the proposed compensating features provide the required level of navigation accuracy and integrity.

(vii) RAIM Implementation. Any algorithm which verifies the integrity of the position output using GPS measurements and barometric aiding is considered a RAIM algorithm. An algorithm which uses additional information (e.g., multi-sensor system) to verify the integrity of the position output may be acceptable as a RAIM-equivalent. Note that if RAIM is not incorporated in the GPS sensor, the sensor is only eligible for Class B3, B4, C3, and C4 certification. For sensors that provide RAIM, add the following requirements to paragraph 2.2.1.13.3 of RTCA/DO-208:

1. The requirements of this paragraph do not apply to equipment certified to class C3 and C4.

2. The RAIM function shall provide a worldwide availability of at least 95% given the optimal 21 GPS constellation (evaluated at a maximum resolution of 3 degrees in latitude, 180 nm in longitude, every 5 minutes). Barometric altitude aiding may be necessary to achieve this availability. RAIM-equivalent functions must also demonstrate an availability of at least 95%. If the equipment incorporates altitude aiding, appropriate requirements can be found in paragraph (a)(5)(xi) of this TSO.

3. The integrated navigation system with which the GPS sensor is interfaced must provide the RAIM function with terminal integrity performance as specified in Table 2-1 of RTCA/DO-208 within 30 nm of the departure and destination points. In addition, approach mode (class C1 equipment) integrity performance shall be provided from 2 nm prior to the final approach fix to the missed approach point. En route integrity performance shall be provided during other conditions.

4. The equipment shall automatically select the RAIM integrity performance requirements applicable to the phase of flight.

5. Equipment certified to class C1 shall provide a RAIM prediction function:

a. This function must automatically predict the availability of RAIM at the final approach fix and missed approach point of an active approach when 2 nm inbound to the final approach fix.

b. This function shall provide the pilot, upon request, a means to determine if RAIM will be available at the planned destination at the estimated time of arrival (ETA) (within at least ±15 minutes computed and displayed in intervals of 5 minutes or less). Once complete almanac data has been received, this capability shall be available at any time after the destination point and estimated time of arrival at that point are established. The availability of corrected barometric altitude (either by automatic or manual altimeter setting input) may be assumed for this purpose. (For the purposes of this calculation, an acceptable value of s_{baro} is 50 meters.) A means to manually identify a satellite that is expected to be unavailable (for scheduled maintenance as identified in an FAA Notice to Airmen) shall be provided. Identification of such a satellite for RAIM prediction purposes should not affect the satellite selection process or deselect that satellite from use in the navigation solution.

c. This function shall display, upon request, RAIM availability at the ETA and over an interval of at least $\pm$15 minutes computed in intervals of 5 minutes or less about the ETA.

6. The GPS equipment shall detect a pseudorange step error greater than 1000 meters, including steps which cause loss of lock for less than 10 seconds. A pseudorange step is defined to be a sudden change in the measured distance to a satellite. If a pseudorange step is detected for a satellite, that satellite shall be excluded from use in the navigation algorithm until its integrity can be verified through fault detection (RAIM). The manufacturer is free to choose any method to calculate the predicted pseudorange or to detect a step. However, any method used should properly take into account satellite movement and aircraft dynamics up to a groundspeed of 750 knots and accelerations up to 14.7 meters/second/second.

(viii) <u>2D Accuracy Requirements (95 percent probability)</u>. In lieu of paragraph 2.2.2 of RTCA/DO-208, substitute the following requirement: The total of error contributions of the airborne equipment shall not exceed the error value listed in this paragraph. The reference spheroid shall use latitude/longitude values corresponding to the WGS-84 ellipsoid (see Appendix B of RTCA/DO-208). Since FTE factors are beyond the control of the equipment manufacturer or installer, these error sources are not included in this paragraph.

GPS RNAV 2D Accuracy Requirements
(95% Confidence)

Error Type	Oceanic (nm)	En Route (random or J/V routes) (nm)	Terminal (nm)	Non-Precision Approach (nm)
Position fixing error*	0.124	0.124	0.124	0.056

* Equipment error assumes an average HDOP of 1.5, GPS equipment waypoint input and output resolution of 0.01 minute for approach/0.1 minute otherwise. Position fixing errors are static values.

(ix) <u>Sensitivity and Dynamic Range</u>. Add the following requirements to paragraph 2.2.3.1 of RTCA/DO-208: Antenna elevation mask angles below 7.5 degrees may be utilized provided the applicant develops acceptable test conditions and supporting analysis to substantiate use of the desired mask angle.

(x) <u>Dynamic Tracking</u>. Add the following requirement to paragraph 2.2.3.4 of RTCA/DO-208: The equipment shall meet the applicable GPS position integrity performance requirements of Table 2-1 within the specified times stated in paragraphs a. and b.

(xi) Pressure Altitude Input Requirements. If the equipment incorporates altitude aiding, the following requirements apply:

1. Pressure altitude data shall not be utilized in GPS sensor certified to class C3 and C4 for RAIM or position determination functions. This requirement does not preclude the use of altitude data for smoothing.

2. Equipment certified to class C1 and C2 shall utilize pressure altitude data in the same manner as described in paragraphs (a)(3)(xx) and (xxi) of this TSO.

(xii) Equipment Test Procedures. Add the following requirement to paragraph 2.5.2 of RTCA/DO-208: For equipment certified to class C3 and C4, paragraphs 2.5.2.5.1 through 2.5.2.5.3.7 do not apply.

(xiii) 2D Functional Performance. In lieu of paragraph 2.5.2.1 of RTCA/DO-208, substitute the following requirement: Each of the functional capabilities identified in subparagraph 2.2.1.11 shall be demonstrated. These capabilities shall be evaluated either by inspection or in conjunction with the tests described in paragraph 2.5.2.

(xiv) 2D Failure Indication. In lieu of paragraph 2.5.2.7 of RTCA/DO-208, substitute the following requirements:

1. Connect the equipment as shown in RTCA/DO-208, Figure 2-2. Remove the electrical power input to the equipment. There shall be a warning indication by the equipment.

2. The tests for the integrity of the navigation signals are specified in subparagraph 2.5.2.5 of RTCA/DO-208. For equipment certified to class C3 and C4, the requirements of this paragraph do not apply.

NOTE: These tests do not need to be performed for functions not incorporated in the equipment.

(6) Satellite Selection. The requirements in paragraph 2.5.2.11 of RTCA/DO-208 apply to satellite selection (for acquisition) as well as during operation (after acquisition). All parameters used for satellite selection shall be re-evaluated at least once every five minutes for each satellite used for positioning. In addition, the following paragraphs clarify minimum parameters to be used during the selection process in paragraph 2.5.2.11 of RTCA/DO-208. The equipment must reject a satellite if:

(i) The health word indicates that the satellite is unhealthy.

(ii) The parity check fails repeatedly, i.e., on more than 5 consecutive words.

(iii) The navigation data contains all 1's, or all 0's.

(iv) The alert flag bit 18 of the Handover Word is set to '1'.

(v) The URA field described in paragraph 2.5.3 of the GPS SPS Signal Specification indicates the absence of an accuracy prediction (value N=15). Note that paragraph 2.5.2.11 of RTCA/DO-208 contains guidance on the use of the URA field and explains that the satellite must also be rejected if the URA > 64 unless additional integrity monitoring validation is performed.

(7) Equipment Performance - Environmental Conditions.

(i) Add the following requirement to paragraph 2.4 of RTCA/DO-208: In addition to the test conditions specified in paragraph 2.4, the equipment shall be subjected to the standards as specified in paragraph 2.2.3.3, Acquisition Time, of RTCA/DO-208.

(ii) The equipment shall output a valid position within 10 seconds after any power fluctuations identified in paragraphs 2.4.13 and 2.4.14 of RTCA/DO-208, including the power outage testing defined in RTCA/DO-160C, Section 16 and 17. During the normal operating conditions tests (2.4.13.1), the equipment shall continue to provide valid navigation information throughout the test. During the abnormal operation conditions tests (2.4.13.2), it is acceptable to indicate a loss of navigation function and manually reset the equipment. For the voltage spike conducted tests, (2.4.14), the equipment shall continue to provide valid navigation information throughout the test.

(8) Radio Frequency Susceptibility Test (Radiated and Conducted). In lieu of paragraph 2.4.17 of RTCA/DO-208, substitute the following requirements:

(i) The equipment shall be subjected to the test conditions as specified in RTCA/DO-160C, Paragraph 20.0. In addition to the requirements specified therein, the equipment shall meet the following requirements of this standard:

1. Subparagraph 2.2.1.1 - Cross-Track Deviation.

2. Subparagraph 2.2.1.2 - Waypoint Distance Display

3. Subparagraph 2.2.1.12 - Equipment Computational Response Time

4. Paragraph 2.2.2 - 2D Accuracy Requirements

5. Subparagraph 2.2.3.3 - Acquisition Time

6. Subparagraph 2.3.1.2 - Vertical Path Deviation

7. Subparagraph 2.3.1.3 - Vertical Profile

8. Paragraph 2.3.2 - VNAV Accuracy Requirements

NOTE: Some of the above references are modified by this TSO. The TSO requirements shall be used instead of the RTCA/DO-208 requirements.

(ii) The GPS equipment shall be shown to meet the requirements of paragraph 2.2.2 of RTCA/DO-208 when subjected to a radiated field strength with continuous wave (cw) interference at a frequency of 1.57542 GHz and an electric field strength of 20 mv/meter measured at the exterior case of the GPS receiver. The radiated susceptibility test procedures of RTCA/DO-160C, Section 20, shall be followed when conducting this test. This test should be conducted with simulated satellite inputs and should not result in the loss of track of any satellite used for navigation. The duration of the test must be sufficient to determine if tracking has been lost (20 seconds should be long enough, depending on the coasting features used by the GPS equipment).

(9) Emission of Radio Frequency Energy Test. Delete the words “(When Required)” from paragraph 2.4.18 of RTCA/DO-208. This test is required.

(10) Antenna Requirements. Add the following requirements to RTCA/DO-208:

(i) The manufacturer shall demonstrate that the antenna (and electronic components included as part of the antenna) meets specified antenna performance requirements when subjected to the environmental test conditions specified in RTCA/DO-160C. The specified antenna performance requirements should include at least minimum and maximum antenna gain, frequency stability, power requirements, noise figure, mask angle, coupling and ground plane requirements, mounting provisions, etc.

(ii) The manufacturer shall provide data to substantiate the maximum airspeed for which the antenna is suitable.

(iii) The manufacturer shall specify in the installation instructions the equipment with which the GPS equipment manufacturer has found the antenna to be compatible. Additionally, the installation instructions shall include the antenna performance specifications (i.e., gain, frequency stability, power requirements, noise figure, mask angle, coupling and ground plane requirements, mounting provisions, etc.).

(iv) The manufacturer shall determine the effects, if any, of ice accumulation on the antenna (including performance) and include this information in the installation instructions.

(11) Environmental Standard. RTCA DO-208 incorporates as a reference RTCA Document DO-160C, “Environmental Conditions and Test Procedures for Airborne Equipment,” dated December 1989.

(12) Software Standard. If the equipment design includes a digital computer, the software must be developed in accordance with RTCA Document No. DO-178B, “Software Considerations in Airborne Systems and Equipment Certification,” dated December 1, 1992. The applicant must develop all software that affects navigation and integrity functions to at least the Level C criteria. For software which was developed to a different software standard, Section 12.1.4 provides a method for upgrading a baseline for software development so that changes can be made in accordance with the criteria contained in RTCA/DO-178B.

NOTE: If the equipment incorporates more than one software level, appropriate partitioning of different software levels is required. If the applicant elects to use the criteria of Level D or Level E when developing software which does not affect navigation or integrity functions, the applicant must substantiate the use of these levels through a safety assessment process as outlined in RTCA/DO-178B.

b. Marking. In addition to the marking specified in 14 CFR Part 21.607(d), the following information shall be legibly and permanently marked on the major equipment components:

(1) Each separate component of equipment that is manufactured under this TSO must be permanently and legibly marked with at least the name of the manufacturer and the TSO number.

(2) With regard to 14 CFR Part 21.607(d)(2), the part number is to include hardware and software identification, or a separate part number may be utilized for hardware and software. Either approach must include a means for showing the modification status.

(3) The software level or levels in accordance with RTCA/DO-178B.

NOTE: If multiple software levels are marked, then the installation instructions must clearly identify the software level for each function.

(4) The equipment class.

c. Data Requirements.

(1) In addition to meeting the requirements of 14 CFR Part 21.605, the manufacturer must furnish the Manager, Aircraft Certification Office (ACO), Federal Aviation Administration, having purview of the manufacturer's facilities, one copy each of the following technical data:

(i) Operating instruction.

(ii) Equipment limitations.

(iii) Installation procedures and limitations (including any necessary sensor interface restrictions for Class B( ) and Class C( ) equipment).

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

(v) Wiring diagrams as applicable to the installation procedures.

(vi) Specifications.

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

(viii) An environmental qualifications form as described in RTCA Document DO-160C for each component of the system.

(ix) Manufacturer's TSO qualification test report.

(x) Nameplate drawing.

(xi) In accordance with RTCA/DO-178B, Paragraph 9.3: Plan for Software Aspects of Certification (PSAC); Software Configuration Index; and Software Accomplishment Summary.

NOTE: The FAA recommends that the PSAC be submitted early in the software development process. Early submittal will allow the applicant to resolve issues with the Software Aspects of Certification Plan, such as partitioning and determination of software levels.

(2) In addition to those data requirements that are to be furnished directly to the FAA, each manufacturer must have available for review by the manager of the ACO having purview of the manufacturer's facilities, the following technical data:

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

(ii) The functional test specification to be used to test each production article to ensure compliance with this TSO.

(iii) Equipment calibration procedures.

(iv) Corrective maintenance procedures (within 12 months after TSO authorization).

(v) Schematic drawings.

(vi) Wiring diagrams.

(vii) The appropriate documentation as defined in RTCA Document DO-178B. All data supporting the applicable objectives found in Annex A, Process Objectives and Outputs by Software Level, must be available for review.

(viii) The results of the environmental qualification tests conducted in accordance with RTCA Document DO-160C.

d. Data to be Furnished with Manufactured Units. One copy of the data and information specified in paragraphs (c)(1)(i) through (viii) of this TSO, and instructions for periodic maintenance and calibration which are necessary for continued airworthiness must go to each person receiving for use one or more articles manufactured under this TSO. In addition, a note with the following statement must be included:

> “The conditions and tests required for TSO 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 aircraft installation conditions are within the TSO standards. The article may be installed only if further evaluation by the applicant documents an acceptable installation and is approved by the Administrator.”

e. Availability of Reference Documents.

(1) Copies of RTCA Document Nos. DO-160C, DO-178B, DO-200, DO-201, DO-208 and DO-229 may be purchased from the RTCA Inc., 1140 Connecticut Avenue, N.W., Suite 1020, Washington, D.C. 20036.

(2) Federal Aviation Regulations Part 21, Subpart O, may be purchased form the Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325. Advisory Circular 20-110 (current revision), “Index of Aviation Technical Standard Orders,” may be obtained from the U.S. Department of Transportation, Utilization and Storage Section, M-443.2, Washington, DC 20590.

/S/ John K. McGrath
Manager, Aircraft Engineering Division
Aircraft Certification Service