tso.c129

C129 Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)

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Department of Transportation

Federal Aviation Administration

Aircraft Certification Service

Washington, DC

(a) Applicability.

(1) Minimum Performance Standard. This technical standard order (TSO) prescribes the minimum performance standard that airborne supplemental area navigation equipment using the 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.

NOTE: The GPS satellite constellation is controlled by the Department of Defense (DOD) and is not dedicated to civilian use at this time. Users of GPS are cautioned that the system is not yet operational and that signal availability and accuracy are subject to change due to an incomplete satellite constellation and operational test activities. Agreements between DOD and the Department of Transportation (DOT) which will define the levels of service to be provided to civilian users have not been finalized.

This TSO reflects minimum performance standards for equipment using signals from the currently planned GPS satellite constellation (21 plus 3 active spares) after it is declared operational. Once the constellation is declared operational, there may be revisions required to the TSO'd equipment and/or installations. The incorporation of other satellite navigation systems and/or follow-on civil satellites may also require revisions in the future.

(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 required 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.).

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)(3)(xv) of this TSO.

2. Class B2. En route and terminal capability only. This equipment provides RAIM capability as specified in paragraph (a)(3)(xv) 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.

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.

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 Federal Aviation Regulation (FAR) 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.)

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)(3)(xv) of this TSO.

2. Class C2. En route and terminal capability only. This equipment provides RAIM capability as specified in paragraph (a)(3)(xv) 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.

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.

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 track angle error may be displayed in conjunction with the display required in paragraph (a)(3)(viii) of this TSO.

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:

	Enroute/ Terminal	Approach Transition[1]	Non-Precision Approach[1]
Full-Scale Deflection (± nm)	5.0	1.0	0.3
Readability (Display only nm)	≤1.0	≤0.1	≤0.3
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%

1 These displays required only for equipment certified to class A1.

2. The applicable non-numeric display information shall be automatically presented upon activation of the appropriate operating mode.

3. A means shall be provided for manual pilot selection of the available display sensitivities including those automatically selected by the system (overriding an automatically selected sensitivity, during an approach, shall cancel the approach mode annunciation). Additionally, the equipment shall display the non-numeric scale sensitivity.

4. 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 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 a 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.

NOTE: Systems providing input resolution of only 0.1 minute may require modification in the future as changes to the National Airspace System occur.

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 requirement:

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.

(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 provide an approach enable alert. After display of this alert, a means shall be provided to enable the approach mode with a single action by the pilot. The approach mode shall not engage unless previously enabled 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).

b. Upon activation of the approach mode, the equipment shall provide a smooth transition from 5 nm non-numeric display sensitivity to 1 nm sensitivity.

c. 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 mode was not previously activated, the approach enable alert shall be repeated.

d. At a distance of 2 nm inbound to the final approach fix, the equipment shall:

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

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

5. 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.

6. A means shall be provided for deselection of the approach mode with a single action by the pilot. 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.

7. 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) Failure/Status Indications. 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.