U.S. Department
of Transportation

Federal Aviation
Administration

Advisory Circular

Subject: **U.S. TERMINAL AND EN ROUTE AREA NAVIGATION (RNAV) OPERATIONS**

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Change:

1. PURPOSE.

a. This advisory circular (AC) provides operational and airworthiness guidance regarding operation on U.S. Area Navigation (RNAV) routes, Standard Instrument Departures (SIDs), and Standard Terminal Arrival Routes (STARs). Operators and pilots should use the guidance in this AC to determine their eligibility for these U.S. RNAV routes and procedures. For the purpose of this guidance, "compliance" means meeting operational and functional performance criteria.

NOTE 1: This AC does not apply to RNAV routes in the Gulf of Mexico ("Q") or Alaska VOR/DME RNAV routes ("JxxxR").

NOTE 2: New applicants for a type certificate (TC) or supplemental type certificate (STC) should include a statement of compliance to this AC and qualification for U.S. RNAV routes and terminal procedures when the aircraft is found in compliance with this AC.

b. Performance-based navigation concept. This AC sets out a series of performance and functional criteria necessary to conduct RNAV procedures. Aircraft compliant with AC 90-45A, Approval of Area Navigation Systems for Use in the U.S. National Airspace System, may not be compliant with criteria contained herein.

c. Approved Global Positioning System (GPS) installations can be used for all public RNAV routes, SIDs, and STARs. Criteria for baseline Distance Measuring Equipment (DME)/DME RNAV systems are defined in appendix 1. Criteria for baseline DME/DME/ Inertial Reference Unit (IRU) RNAV systems are defined in appendix 2. Aircraft meeting these baseline criteria will conform to the designed procedure.

d. This criterion is generally consistent with the criteria for Precision RNAV (P-RNAV) operations in Europe (reference proposed AC 90-96A, Approval of U.S. Operators and Aircraft to Operate Under Instrument Flight Rules (IFR) in European Airspace Designated for Basic Area Navigation (B-RNAV) and Precision Area Navigation (P-RNAV) and JAA TGL-10). Exceptions to the P-RNAV criteria include:

- GPS equipped aircraft compliant with AC 90-USRNAV need not perform the GPS health word checking described in TSO-C129A, Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS).

- All classes of TSO-C129/C129A equipment certified for IFR-use without deviation may execute U.S. RNAV procedures and routes implemented with a requirement for compliance with this AC.

2. RELATED CFR SECTIONS.

Title 14 of the Code of Federal Regulations (14 CFR), Part 91, sections 91.123 and 91.205; Part 95; Part 121, section 121.349; Part 125, section 125.203; Part 129, section 129.17; and Part 135, section 135.165.

3. DEFINITIONS.

For the purpose of operations on RNAV routes and procedures, the following definitions are provided:

a. Area Navigation (RNAV) System. A method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these. For the purposes of this AC, RNAV systems include position inputs from GPS and DME, as well as IRU. Criteria for DME/DME RNAV systems are discussed in appendix 1, and criteria for DME/DME/IRU RNAV systems are discussed in appendix 2.

b. Critical DME. A DME facility that, when unavailable, results in inadequate RNAV system performance to sustain operations along a specific route or procedure. The required performance assumes an aircraft's RNAV system meets the minimum standard (baseline) for DME/DME RNAV systems found in appendix 1, or the minimum standard for DME/DME/IRU systems found in appendix 2. For example, terminal RNAV SIDs and STARs, and RNAV routes may be published with only two DMEs, in which case, both are critical.

c. Global Navigation Satellite System (GNSS). The GNSS is a worldwide position and time determination system, which includes one or more satellite constellations, aircraft receivers, and system integrity monitoring. GNSS is augmented as necessary to support the required navigation performance for the actual phase of operation.

d. Global Positioning System (GPS). The U.S. GNSS core satellite constellation providing space-based positioning, velocity, and time. GPS is composed of space, control, and user elements. The space element is nominally composed of at least 24 satellites in 6 orbital planes. The control element consists of five monitor stations, three ground antennas and a master control station. The user element consists of antennas and receiver processors providing positioning, velocity, and precise timing to the user.

e. Q Route. "Q" is the designator assigned to include Contiguous United States Area Navigation Routes published in FAA Order 7400.9L.

f. Receiver Autonomous Integrity Monitoring (RAIM). A technique used within a GPS receiver/processor to monitor GPS signal performance. This integrity determination is achieved by a consistency check among redundant measurements.

g. Type A RNAV SIDs and STARs. RNAV terminal procedures requiring system performance currently met by GPS or DME/DME RNAV systems satisfying the criteria discussed in this AC. Type A terminal procedures require the aircraft's track keeping accuracy remain bounded by ±2 NM for 95% of the total flight time.

h. Type B RNAV SIDs and STARs. Procedures requiring system performance currently met by GPS or DME/DME/IRU RNAV systems satisfying the criteria discussed in this AC. Type B procedures may require the aircraft's track keeping accuracy remain bounded by ±1 NM for 95% of the total flight time.

i. Track Keeping Accuracy. This value includes signal source error, airborne receiver error, display system error, and flight technical error. This navigation performance assumes the necessary coverage provided by satellite or ground based navigation aids is available for the intended route to be flown.

4. RELATED READING MATERIALS. (NOTE: All references to the edition are current as of the publication date of this AC).

a. Technical Standard Order (TSO) C66C, Distance Measuring Equipment (DME) Operating within the Radio Frequency Range of 960-1215 Megahertz.

b. TSO C115B, Airborne Area Navigation Equipment Using Multi-Sensor Inputs.

c. TSO C129A, Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS).

d. TSO C145A, Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS).

e. TSO C146A, Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS).

f. FAA AC 20-121, Airworthiness Approval of Airborne LORAN-C Navigation Systems for Use in the U.S. National Airspace System (NAS).

g. AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors.

h. AC 20-138A, Airworthiness Approval of Global Navigation Satellite System (GNSS) Equipment.

i. AC 25-4, Inertial Navigation Systems (INS).

j. AC 25-7A, Flight Test Guide for Certification of Transport Category Airplanes.

k. AC 25-15, Approval of Flight Management Systems in Transport Category Airplanes.

l. AC 90-45A, Approval of Area Navigation Systems for Use in the U.S. National Airspace System.

m. AC 90-94, Guidelines for Using Global Positioning System Equipment for IFR En Route and Terminal Operations and for Non-Precision Instrument Approaches in the U.S. National Airspace System.

n. AC 90-96A, Approval of U.S. Operators and Aircraft to Operate Under Instrument Flight Rules (IFR) in European Airspace Designated for Basic Area Navigation (B-RNAV) and Precision Area Navigation (P-RNAV).

o. FAA Order 7470.1, Distance Measuring Equipment (DME)/DME Infrastructure Evaluations for Area Navigation (RNAV) Routes and Procedures

p. JAA ACJ20X5 - Guidance Material on Airworthiness Approval and Operational Criteria for the use of the Navstar Global Positioning System (GPS) (formerly known as JAA TGL-3).

q. JAA TGL-10, Airworthiness and Operational Approval for Precision RNAV Operations in Designated European Airspace and the corresponding JAA TGL-10 Frequently Asked Questions (FAQ) Document.

r. RTCA/DO-178B, Software Considerations in Airborne Systems and Equipment Certification.

s. RTCA/DO-187, Minimum Operational Performance Standards for Airborne Area Navigation Equipment Using Multi-Sensor Inputs.

t. RTCA/DO-189, Minimum Performance Standard for Airborne Distance Measuring Equipment (DME) Operating Within the Radio Frequency Range of 960-1215 Megahertz.

u. RTCA/DO-200A, Standards for Processing Aeronautical Data.

v. RTCA/DO-201A, Standards for Aeronautical Information.

w. RTCA/DO-208, Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS).

x. RTCA/DO-236B, Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation.

y. RTCA/DO-283A, Minimum Operational Performance Standards for Required Navigation Performance for Area Navigation.

5. ASSUMPTIONS APPLICABLE TO RNAV ROUTES, SIDS, AND STARS.

a. Operation on U.S. RNAV routes, SIDs, and STARs:

(1) Relies on conventional compliance with descent profiles and altitude requirements;

NOTE: Pilots operating aircraft with an approved Baro-VNAV system may continue to use their Baro-VNAV system while executing U.S. RNAV routes, SIDs, and STARs. Operators must ensure compliance with all altitude constraints as published in the procedure by reference to the barometric altimeter.

(2) Does not require the pilot to monitor ground-based NAVAIDs used in position updating unless required by the Airplane Flight Manual (AFM);

(3) Bases obstacle clearance assessments on the associated required system performance; and

(4) Guidance in this AC does not supersede appropriate operating requirements for equipage. For example, Part 91 can have a single RNAV system, and Part 121 can have a single RNAV system and another independent navigation system allowing safe flight to a suitable alternate airport.

b. The DME navigation infrastructure supporting the design of an RNAV route or procedure has been assessed and validated by the FAA. This includes analysis by FAA flight inspection assets. DME coverage may use Expanded Service Volume (ESV) for select DME facilities so that there is no requirement to use VOR, LOC, NDB, or AHRS during normal operation of the DME/DME RNAV system. ESV facilities require a satisfactory flight inspection prior to use.

c. If any critical DME facilities exist, they are identified within the relevant U.S. Flight Information Publications (FLIP).

d. Unless the RNAV route, SID, or STAR specifically requires GPS or GNSS equipage, aircraft on the RNAV route, SID, or STAR must be within ATC radar surveillance and communication.

e. All DME ground stations maintained by the FAA and used to define the availability of these RNAV routes, SIDs, and STARs comply with applicable ICAO standards.

6. SYSTEM PERFORMANCE.

a. Navigation System Accuracy.

(1) Q Routes: Aircraft operating on RNAV routes must maintain a track keeping accuracy bounded by ±2 NM for 95% of the total flight time. These routes will be referenced in the remainder of this AC as "RNAV routes."

(2) Type A RNAV SIDs and STARs. Aircraft operating on Type A RNAV SIDs and STARs must maintain a track keeping accuracy bounded by ±2 NM for 95% of the total flight time.

(3) Type B RNAV SIDs and STARs. Aircraft operating on Type B RNAV SIDs and STARs must maintain a track keeping accuracy bounded by ±1 NM for 95% of the total flight time.

b. Navigation Sensors. U.S. RNAV operations are based upon the use of RNAV equipment that automatically determines aircraft position in the horizontal plane using inputs from the following types of positioning sensors (no specific priority). Although LORAN-C can meet 2.0 NM terminal track-keeping performance, complete criteria to allow its use in terminal airspace operations has not been developed.

(1) Global Navigation Satellite System (GNSS) in accordance with TSO-C145A, TSO-C146A, and TSO-C129/C129A.

NOTE: Positioning data from other types of navigation sensors may be integrated with the GNSS data provided it does not cause position errors exceeding the track keeping accuracy requirements.

(2) DME/DME RNAV equipment complying with the criteria in appendix 1.

NOTE 1: For the purposes of this AC, this equipment cannot be used to meet the track keeping accuracy requirement for Type B RNAV SIDs and STARs.

NOTE 2: For Type A SIDs/STARs, VOR/DME coverage is not assessed in procedure design, but normal functioning of the flight management system (FMS) coupled with the DME evaluation and radar monitoring should provide sufficient navigation capability.

(3) DME/DME/IRU RNAV equipment complying with the criteria in appendix 2.

NOTE: For Type B SIDs/STARs, multi-sensor RNAV systems may utilize VOR/DME updating prior to IRU updating. Normal functioning of the FMS coupled with the DME evaluation and radar monitoring should provide sufficient navigation capability.

c. Navigation Displays and Functions.

(1) The display of navigation data must use either a lateral deviation display or a navigation map display, meeting the following requirements:

(a) A non-numeric lateral deviation display (for example, CDI, (E)HSI), with a To/From indication and a failure annunciation, for use as primary flight instruments for navigation of the aircraft, for maneuver anticipation, and for failure/status/integrity indication, with the following four attributes:

1. Must be visible to the pilot and located in the primary field of view (± 15 degrees from pilot's normal line of sight) when looking forward along the flight path.

2. Lateral deviation scaling should agree with any alerting and annunciation limits, if implemented.

3. Lateral deviation display must be automatically slaved to the RNAV computed path. The lateral deviation display must also have a full-scale deflection suitable for the current phase of flight and must be based on the required track-keeping accuracy. The course selector of the deviation display should be automatically slewed to the RNAV computed path, or the pilot must adjust the CDI or HSI selected course to the computed desired track.

NOTE: The normal function of stand-alone GNSS equipment meets this requirement.

4. Display scaling may be set automatically by default logic or set to a value obtained from a navigation database. The full-scale deflection value must be known or must be available for display to the pilot commensurate with en route, terminal, or approach values.

(b) A navigation map display, readily visible to the pilot, with appropriate map scales (scaling may be set manually by the pilot), and giving equivalent functionality to a lateral deviation display.

(2) Capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft (primary navigation display), the RNAV computed desired path and aircraft position relative to the path.

(3) Where the minimum flight crew is two pilots, means for the pilot not flying to verify the desired path and the aircraft position relative to the path.

(4) A navigation database, containing current navigation data officially promulgated for civil aviation, which can be updated in accordance with the Aeronautical Information Regulation and Control (AIRAC) cycle and from which terminal airspace procedures can be retrieved and loaded into the RNAV system. The stored resolution of the data must be sufficient to achieve the required track keeping accuracy. The database must be protected against pilot modification of the stored data.

(5) Means to display the validity period of the navigation data to the pilot.

(6) Means to retrieve and display data stored in the navigation database relating to individual waypoints and navigation aids, to enable the pilot to verify the procedure to be flown.

(7) Capacity to load from the database into the RNAV system the entire RNAV segment of the SID or STAR procedure(s) to be flown.

(8) Display of the active navigation sensor type, either in the pilot's primary field of view, or on a readily accessible page on an MCDU.

(9) Display of the identification of the active (To) waypoint, either in the pilot's primary field of view or on a readily accessible page on an MCDU, readily visible to the pilot.

(10) Display of distance and bearing to the active (To) waypoint in the pilot's primary field of view. Where impracticable, the data may be displayed on a readily accessible page on an MCDU, readily visible to the pilot.

(11) Display of ground speed or time to the active (To) waypoint, either in the pilot's primary field of view, or on a readily accessible page on a MCDU, readily visible to the pilot.

(12) The system must be capable of displaying lateral deviation with a resolution of at least 0.1 NM.

(13) Capability for the navigation system to execute a "Direct to" function.

(14) Capability for automatic leg sequencing with display of sequencing to the pilot.

(15) Capability to execute procedures extracted from the onboard database including the capability to execute fly-over and fly-by turns.

(16) Capability to execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators, or their equivalent:

Initial Fix (IF)

Track to Fix (TF)

Course to Fix (CF)

Direct to Fix (DF)

NOTE 1: Path terminators are defined in ARINC Specification 424, and their application is described in more detail in RTCA documents DO-236B and DO-201A.

NOTE 2: Heading to Altitude (VA), Heading to Manual termination (VM) and Course to Altitude (CA) capabilities are recommended functions.

(17) If all or part of an RNAV route is entered through the manual entry of fixes from the navigation database, TF leg type must be used to define the path between a manually entered fix and the preceding and following fixes.

(18) Capability to display an indication of the RNAV system failure, including the associated sensors, in the pilot's primary field of view.

(19) For multi-sensor systems, capability for automatic reversion to an alternate RNAV sensor if the primary RNAV sensor fails.

NOTE: This does not preclude providing a means for manual navigation source selection.

7. ELIGIBLE AIRCRAFT SYSTEMS.

a. Aircraft with a statement of compliance to this AC in their Aircraft Flight Manual (AFM), Pilot Operating Handbook (POH), or the operating manual for their avionics meet the performance and functional requirements of this AC.

b. Aircraft with P-RNAV approval based on GNSS capability meet the functional requirements of this AC. Due to differences in radio navigation infrastructure in the United States, if the approval is based on DME/DME or DME/DME/IRU, the operator should ensure the equipment meets the criteria in appendix 1 or 2, as applicable.

c. The following systems meet the functional and accuracy requirements of this AC. The RAIM prediction program should comply with the criteria in AC 20-138A, paragraph 12.

(1) Aircraft with TSO-C129/C129A sensor (Class B or C) and the requirements in a TSO-C115B FMS, installed for IFR use IAW AC 20-130A.

(2) Aircraft with TSO-C145A sensor, and the requirements in a TSO-C115B FMS, installed for IFR use IAW AC 20-130A or AC 20-138A.

(3) Aircraft with TSO-C129/C129A Class A1 (without deviation) or TSO-C146A equipment installed for IFR use IAW AC 20-138 or AC 20-138A.

NOTE: Refer to paragraph 4 for TSO and AC references.

d. Aircraft with a statement from the manufacturer documenting compliance with the criteria in this AC (paragraph 6, appendix 1 or 2). These statements should include the airworthiness basis for compliance. Compliance with the sensor requirements in paragraph 6b will have to be determined by the equipment or aircraft manufacturer, while compliance with the functional requirements in paragraph 6c may be determined by the manufacturer or by inspection by the operator.

NOTE 1: Aircraft with a demonstrated RNP capability will annunciate when no longer satisfying the performance requirement associated with the operation. However, for DME/DME and DME/DME/IRU-based operations, the manufacturer still has to determine compliance with appendix 1 or 2 to support evaluation of the DME infrastructure.

NOTE 2: Aircraft with a TSO-C129 GPS sensor and a TSO-C115 or C115A FMS meet many of the requirements defined in this AC. Such equipment would require further evaluation by the manufacturer against all the functional and performance requirements in this AC.

8. U.S. RNAV OPERATING PROCEDURES.

Pilots should be familiar with the normal operating and contingency procedures associated with U.S. RNAV routes, SIDs, and STARs.

a. Pre-flight Planning.

(1) Operators and pilots intending to conduct operations on U.S. RNAV routes, SIDs, and STARs are expected to file the appropriate flight plan suffix code as designated in the current Aeronautical Information Manual (AIM) and other FLIP.

(2) During the pre-flight planning phase, the availability of the navigation infrastructure, required for the intended routes, SIDs, and STARs, including any non-RNAV contingencies, must be confirmed for the period of intended operations. The pilot must also confirm availability of the onboard navigation equipment necessary for the route, SID, or STAR to be flown.

(3) **The onboard navigation data** must be current and appropriate for the region of intended operation and must include the navigation aids, waypoints, and relevant coded terminal airspace procedures for the departure, arrival, and alternate airfields.

NOTE: Navigation databases are expected to be current for the duration of the flight. If the AIRAC cycle will change during flight, operators and pilots should establish procedures to ensure the accuracy of navigation data, including suitability of navigation facilities used to define the routes and procedures for flight. Traditionally, this has been accomplished by verifying electronic data against paper products. One acceptable means is to compare aeronautical charts (new and old) to verify navigation fixes prior to dispatch. If an amended chart is published for the procedure, the database must not be used to conduct the operation.

(4) **If not equipped with GPS** (or for multi-sensor systems with GPS which do not alert upon loss of GPS), aircraft must be capable of navigation system updating using DME/DME or DME/DME/IRU for Type A SIDs and STARs and DME/DME/IRU for Type B SIDs and STARs. For procedures requiring GPS, if the navigation system does not automatically alert the flight crew of a loss of GPS, the operator must develop procedures to verify correct GPS operation.

(5) **If TSO-C129 equipment** is used to satisfy the RNAV requirement, the pilot should confirm the availability of RAIM with the latest GPS NOTAMs. If no GPS satellites are scheduled to be out-of-service, then the aircraft can depart without further action. If, however, any GPS satellites are scheduled to be out-of-service, then the availability of GPS integrity (RAIM) must be confirmed for the intended flight (route and time). In the event of a predicted, continuous loss of RAIM of more than five (5) minutes for any part of the intended flight, the flight should be delayed, canceled, or re-routed where RAIM requirements can be met. Operators using WAAS avionics must check WAAS NOTAMs.

b. General Operating Procedures. Operators and pilots should not request or file U.S. RNAV routes or procedures unless satisfying the criteria in this AC. If an aircraft not meeting these criteria receives a clearance from ATC to conduct an RNAV procedure, the pilot must advise ATC that he/she is unable to accept the clearance and request alternate instructions.

(1) **The pilot should comply with any instructions** or procedures identified by the manufacturer as necessary to comply with the equipment requirements of this AC. Pilots of RNP aircraft must adhere to any AFM limitations or operating procedures required to maintain the RNP value specified for the procedure.

(2) **At system initialization,** pilots must confirm the navigation database is current and verify the aircraft's present position.

(3) **Pilots must not fly an RNAV SID or STAR unless it is retrievable by procedure name** from the onboard navigation database and conforms to the charted procedure.

NOTE: SIDs and STARs excluding the use of RNAV DME/DME and DME/DME/IRU navigation will be annotated on the chart with a requirement for GPS/GNSS.

(4) Whenever possible, RNAV routes should be extracted from the database in their entirety, rather than loading RNAV route waypoints from the database into the flight plan individually. Selecting and inserting individual, named fixes is permitted, provided all fixes along the published route to be flown are inserted.

NOTE: This does not preclude the use of panel-mount GPS avionics to meet the requirements of this AC.

(5) Flight crews should crosscheck the cleared flight plan against charts or other applicable resources, as well as the navigation system textual display and the aircraft map display, if applicable. If required, confirm exclusion of a specific navigation aid. A procedure should not be used if doubt exists as to the validity of the procedure in the navigation database.

NOTE: Pilots may notice a slight difference between the navigation information portrayed on the chart and their primary navigation display. Differences of 3° or less may result from equipment manufacturer's application of magnetic variation and are operationally acceptable.

(6) If GPS is not available, aircraft must be capable of navigation using DME/DME or DME/DME/IRU for Type A SIDs and STARs; and aircraft must be capable of navigation using DME/DME/IRU for Type B SIDs and STARs.

(7) Manual entry (latitude/longitude, place/bearing) of published procedure waypoints into the aircraft system is not permitted. Additionally, pilots must not change any RNAV SID or STAR database waypoint type from a fly-by to a fly-over or vice versa.

(8) While operating on RNAV segments, pilots are encouraged to use flight director and/or autopilot in lateral navigation mode, if available.

NOTE: Pilots and operators should be aware of possible lateral deviations when using raw data or Navigation Map Displays for lateral guidance in lieu of flight director.

(9) If ATC issues a heading assignment taking the aircraft off a procedure, the pilot should not modify the route in the RNAV system until a clearance is received to rejoin the procedure or the controller confirms a new route clearance. When the aircraft is not on the published procedure, the specified accuracy requirement (paragraph 7a) does not apply.

c. RNAV SID Specific Requirements. Prior to commencing takeoff, the pilot must verify the aircraft's RNAV system is available, operating correctly, and the correct airport and runway data are loaded.

(1) RNAV Engagement Altitudes. For Type A SIDs, the pilot must be able to engage RNAV equipment no later than 2,000 feet above airport elevation. For Type B SIDs, the pilot must be able to engage RNAV equipment no later than 500 feet above airport elevation.

(2) Type B SIDs.

(a) Pilots must use a CDI/flight director and/or autopilot, in lateral navigation mode. Other methods providing an equivalent level of performance may be acceptable.

(b) The full-scale deflection value must be known or made available for display to the flight crew. A value of ±1 NM is acceptable. Pilots of RNP aircraft should select an RNP level meeting this functionality.

(3) DME/DME/IRU (D/D/I) Aircraft. Pilots of aircraft without GPS, using DME/DME/IRU, must ensure the aircraft navigation system position is confirmed, within 1,000 feet, at the start point of take-off roll. The use of an automatic or manual runway update is an acceptable means of compliance with this requirement. A navigation map may also be used to confirm aircraft position, if pilot procedures and display resolution allow for compliance with the 1,000-foot tolerance requirement.

(4) GNSS Aircraft. When using GNSS, the signal must be acquired before the take-off roll commences.

NOTE 1: The requirements of paragraph 8c(1), (2), and (3) help to ensure aircraft RNAV system performance meets procedure design criteria.

NOTE 2: For aircraft using TSO-C129/C129A equipment, the departure airport must be loaded into the flight plan in order to achieve the appropriate navigation system monitoring and sensitivity.

d. Contingency Procedures. The pilot must notify ATC of any loss of the RNAV capability, together with the proposed course of action. If unable to comply with the requirements of an RNAV procedure, pilots must advise Air Traffic Control as soon as possible. For example, ". . .N1234, failure of GPS system, unable RNAV, request amended clearance." The loss of RNAV capability includes any failure or event causing the aircraft to no longer satisfy the criteria of this AC. Example failures include loss of autopilot/flight director (if required), or reversion to navigation other than GNSS, DME/DME, or DME/DME/IRU (even though no pilot monitoring of navigation updating source is required).

9. PILOT KNOWLEDGE REQUIREMENTS AND TRAINING.

The pilot is expected to be knowledgeable in the following areas. Also, for Parts 121, 125, 129, 135, and 91 Subpart K operators, the approved training program should address the elements listed below. This training program should provide sufficient training (for example, simulator,

training device, or aircraft) on the aircraft's RNAV system to the extent that the pilots are not just task oriented.

a. The information in this AC.

b. The meaning and proper use of Aircraft Equipment/Navigation Suffixes.

c. Procedure characteristics as determined from chart depiction and textual description.

(1) Depiction of waypoint types (fly-over and fly-by) and path terminators (provided in paragraph 6c(16) and any other types used by the operator) as well as associated aircraft flight paths.

(2) Required navigation equipment for operation on RNAV routes, SIDs, and STARs (for example, DME/DME, DME/DME/IRU, GNSS).

d. RNAV system-specific information:

(1) Levels of automation, mode annunciations, changes, alerts, interactions, reversions, and degradation.

(2) Functional integration with other aircraft systems.

(3) The meaning and appropriateness of route discontinuities as well as related flight crew procedures.

(4) Monitoring procedures for each phase of flight (for example, monitor PROG or LEGS page).

(5) Types of navigation sensors (for example, DME, IRU, GNSS) utilized by the RNAV system and associated system prioritization/weighting/logic.

(6) Turn anticipation with consideration to speed and altitude effects.

(7) Interpretation of electronic displays and symbols.

e. RNAV equipment operating procedures, as applicable, including how to perform the following actions:

(1) Verify currency of aircraft navigation data.

(2) Verify successful completion of RNAV system self-tests.

(3) Initialize RNAV system position.

(4) Retrieve and fly a SID or STAR with appropriate transition.

(5) Adhere to speed and/or altitude constraints associated with a SID or STAR.

(6) Make a runway change associated with a SID or STAR.

(7) Verify waypoints and flight plan programming.

(8) Perform a manual or automatic runway update (with takeoff point shift, if applicable).

(9) Fly direct to a waypoint.

(10) Fly a course/track to a waypoint.

(11) Intercept a course/track.

(12) Be vectored off and rejoin a procedure.

(13) Determine cross-track error/deviation.

(14) Insert and delete route discontinuity.

(15) Remove and reselect navigation sensor input.

(16) When required, confirm exclusion of a specific navigation aid or navigation aid type.

(17) Insert and delete lateral offset.

(18) Change arrival airport and alternate airport.

f. Operator-recommended levels of automation for phase of flight and workload, including methods to minimize cross-track error to maintain procedure centerline.

/s/ John M. Allen for
James J. Ballough
Director, Flight Standards Service

APPENDIX 1. BASELINE AREA NAVIGATION (RNAV) SYSTEM CRITERIA FOR DISTANCE MEASURING EQUIPMENT (DME)

1. PURPOSE.

The FAA is responsible for evaluating DME/DME coverage and availability against a minimum standard DME/DME RNAV system for each route and procedure. Detailed criteria defining DME/DME RNAV system performance as it relates to the DME infrastructure is needed. This appendix defines the minimum performance and functions (baseline) for DME/DME RNAV systems intended to support the implementation of RNAV routes, Type A Standard Instrument Departures (SIDs) and Standard Terminal Arrivals (STARs) with a track keeping accuracy performance of 2.0 NM (95%). These criteria may be applied under an airworthiness approval for new equipment or used by the manufacturer for self-certification of existing equipment.

2. MINIMUM REQUIREMENTS FOR DME/DME RNAV SYSTEM.

a. Tuning and Updating Position of DME Facilities. The DME/DME RNAV system must:

(1) Position update within 30 seconds of tuning DME navigation facilities.

(2) Auto-tune multiple DME facilities.

(3) Provide continuous DME/DME position updating. (Given a third DME facility or a second pair has been available for at least the previous 30 seconds, there must be no interruption in DME/DME positioning when the RNAV system switches between DME stations/pairs.)

b. Using Facilities in the Airport/Facility Directory. The FAA cannot ensure all DME signals within reception distance of U.S. airspace meet International Civil Aviation Organization (ICAO) standards. These could include non-U.S. DME facilities, or Department of Defense (DOD) maintained DME facilities excluded from the National Airspace System (NAS) database. DME/DME RNAV procedure design will only use DME facilities listed in the Airport/Facility Directory (A/FD). Although a procedure design issue, applicants may mitigate this restriction by:

(1) Having the DME/DME RNAV system only use DME facilities listed in the A/FD.

(2) Requiring exclusion of non-NAS DME facilities from the aircraft's navigation database when the RNAV routes or procedures are within reception range of these non-NAS DME facilities.

(3) Demonstrating to the FAA that their RNAV system performs reasonableness checks to detect errors from the non-NAS DME facilities and excludes these facilities from the navigation position solution when appropriate (e.g., using the ARINC 424 coding to preclude tuning co-channel DME facilities when the DME facilities signals-in-space overlap). See paragraph 3 for guidance on testing of reasonableness checks.

c. DME Facility Relative Angles. When needed to generate a DME/DME position, FMS must use, as a minimum, DMEs with a relative include angle between 30° and 150°. The FMS may use DME pairs outside these angles (for example, 20° to 160°).

d. RNAV System Use of DMEs. The RNAV system may use any receivable DME facility (listed in the A/FD) regardless of its location. When needed to generate a DME/DME position, as a minimum, the RNAV system must use an available and valid low altitude and/or high altitude DME anywhere within the following region around the DME facility:

(1) Greater than or equal to 3 NM from the facility; and

(2) Less than 40 degrees above the horizon when viewed from the DME facility; and

(3) For facilities with an ARINC 424 figure of merit (FOM):

If the ARINC 424 FOM is:	**The aircraft's DME/DME RNAV system must be**:	
	Less than or equal to:	**And less than:**
0	40 NM from the facility	12,000 ft above facility elevation
1	70 NM from the facility	18,000 ft above facility elevation
2	130 NM from the facility	--
3	160 NM from the facility	--

NOTE 1: Many RNAV systems can use additional DME facilities (for example, LOC DMEs or DMEs outside this region). RNAV systems are not required to use the FOM value.

NOTE 2: RNAV routes and procedures may include new FOMs with Expanded Service Volumes.

(4) A valid DME facility:

(a) Broadcasts an accurate facility identifier signal,

(b) Satisfies the minimum field strength requirements, and

(c) Is protected from other interfering DME signals according to the co-channel and adjacent channel requirements.

e. No Requirement to Use VOR, NDB, LOC, IRU or AHRS. There is no requirement to use VOR (VHF omni-range), LOC (localizer), NDB (non-directional beacon), IRU (inertial reference unit) or AHRS (attitude heading reference system) during normal operation of the DME/DME RNAV system.

f. Position Estimation Accuracy. A minimum of two DME facilities satisfying the criteria in paragraph 2, and any other valid DME facilities not meeting that criteria, the 95% position estimation accuracy must be better than or equal to 1.75 NM. A flight technical error contribution not exceeding 1.0 NM (95%) may be assumed.

NOTE: This performance requirement is met for any navigation system that uses two DME stations simultaneously, limits the DME inclusion angle to between 30 and 150° and uses DME sensors that meet the accuracy requirements of TSO-C66C. If the RNAV system uses DME facilities outside the range identified above, the DME signal-in-space error can be assumed to be 0.1 NM 95%.

g. Preventing Erroneous Guidance from Co-Channel Facilities. The RNAV system must ensure co-channel DME facilities do not cause erroneous guidance. This could be accomplished by including VOR reasonableness checking when initially tuning a DME facility or excluding a DME facility when there is a co-channel DME within line-of-sight. See paragraph 3 for guidance on testing of reasonableness checks.

NOTE: The DME assessment cannot use a DME facility when there is a co-channel DME facility within line-of-sight.

h. Preventing Erroneous VOR Signals-in-Space. The RNAV system must ensure an erroneous VOR signal-in-space does not cause the position accuracy to exceed 1.75 NM. This could be accomplished by not using VOR signals when DME/DME will be available or weighting and/or monitoring the VOR signal with DME/DME to ensure it does not mislead position results (for example, through reasonableness checks). See paragraph 3 for guidance on testing of reasonableness checks.

i. Ensuring RNAV Systems Use Operational Facilities. The RNAV system must use operational DME facilities. DME facilities listed by NOTAM as unavailable (for example, under test or other maintenance) could still reply to an airborne interrogation. (Therefore, non-operational facilities must not be used.) An FMS may exclude non-operational facilities by checking the identification or inhibiting the use of facilities identified as not operational.

j. Operational Mitigations. Operational mitigations defined to qualify equipment with this AC will not require pilot action during critical phases of flight, pilot monitoring of the RNAV system's navigation updating source(s), or time intensive programming/ blackballing of multiple DME stations prior to executing a procedure.

NOTE 1: Blackballing single facilities listed by NOTAM as out-of-service and/or programming route/procedure-defined "critical" DME is acceptable when this mitigation requires no pilot action during a critical phase of flight. A programming requirement also does not imply the pilot should complete manual entry of DME facilities which are not in the navigation database. Instead, this allows RNAV systems to tune a critical DME, as appropriate to a specific route or procedure.

NOTE 2: The critical phase of flight is normally from the final approach fix on an approach procedure through missed approach, or from field elevation to 2,500 ft above airport elevation on a departure.

3. REASONABLENESS CHECKS.

Many FMSs perform a reasonableness check to verify valid DME measurements. Reasonableness checks are very effective against database errors or erroneous system acquisition (such as co-channel facilities), and typically fall into two classes:

- Those the FMS uses after it acquires a new DME. The FMS compares the aircraft's position before using the DME to the aircraft's range to the DME, and

- Those the FMS continuously uses, based on redundant information (for example, extra DME signals or IRU data).

a. General Requirements. The reasonableness checks are intended to prevent navigation aids from being used for navigation update in areas where the data can lead to radio position fixing errors due to co-channel interference, multipath, and direct signal screening. In lieu of using radio navigation aid published service volume, the navigation system should provide checks, which preclude use of duplicate frequency NAVAIDs within range, over-the-horizon NAVAIDs, and use of NAVAIDs with poor geometry.

b. Assumptions. Under certain conditions, reasonableness checks can be invalid.

(1) Do not assume a DME signal remains valid just because it was valid when acquired.

(2) Do not assume extra DME signals are available. The intent of this baseline is to support operations where the infrastructure is minimal (for example, when only two DMEs are available for parts of the procedure).

c. Use Stressing Conditions to Test Effectiveness. When an applicant uses a reasonableness check to satisfy any requirement in this AC, they must test the effectiveness of the check under stressing conditions. An example of this condition is a DME signal that is valid at acquisition and ramps off during the test (similar to what a facility under test might do), when there is only one other supporting DME or two signals of equal strength.

4. PERFORMANCE CONFIRMATION PROCESS.

New systems may demonstrate compliance with these criteria as part of the airworthiness approval. For existing systems, the manufacturer should determine compliance with the equipment and aircraft criteria in this appendix. Manufacturers who have achieved their compliance should provide this information by letter to their customers. Operators/pilots may use this approval as a basis for their operations. Manufacturers are also requested to provide a copy of this letter to Flight Technologies and Procedures Division, AFS-400, (202) 385-4586, to facilitate making this information available to all operators. Guidance is provided below for both an airplane manufacturer and FMS and DME manufacturers.

a. Airplane manufacturer (Type Certificate (TC) holders incorporating FMS and DME/DME positioning). The manufacturer should review the available data for the integrated navigation system, and obtain additional data as appropriate, to determine compliance with the criteria in this AC. Those manufacturers who have achieved compliance with the criteria should provide this information by letter to their customers. Manufacturers are also requested to provide a copy of this letter to AFS-400, to facilitate making this information available to all operators.

b. Equipment manufacturers (typically separate Technical Standard Order (TSO) DME and FMS holders).

(1) DME Sensor. The only requirement in this appendix that needs to be considered for a DME sensor is the accuracy requirement. DME sensors have been demonstrated to a variety of performance requirements per TSO-C66, Distance Measuring Equipment (DME) Operating within the Radio Frequency Range of 960-1215 Megahertz.

(a) TSO-C66 performance standards have evolved as follows:

1. TSO-C66: (Aug 1960) RTCA/DO99.

2. TSO-C66A: (Sep 1965) RTCA/DO151, accuracy requirement as total error with 0.1 NM attributed to ground facility, airborne equipment accuracy of 0.5 NM or 3% of distance, whichever is greater, with a maximum of 3 NM.

3. TSO-C66B: (Nov 1978) RTCA/DO151a, accuracy requirement as total error with 0.1 NM attributed to ground facility, airborne equipment accuracy of 0.5 NM or 1% of distance, whichever is greater, with a maximum of 3 NM.

4. TSO-C66C: (Sept 1985) RTCA/DO189, accuracy requirement as total error for the airborne equipment of 0.17 NM or 0.25% of distance, whichever is greater.

(b) The accuracy required by TSO-C66C is adequate to support the criteria in this appendix, and DME equipment manufacturers under these versions of the TSO do not need to further evaluate their equipment for Type A operations. DME sensor manufacturers may use the following process to establish more accurate performance than originally credited.

1. Determining Achieved Accuracy. Rather than relying on original demonstrated performance, the applicant may elect to review the original TSO or TC/STC test data to determine the demonstrated accuracy and/or make any appropriate changes to qualification tests to determine achieved accuracy.

NOTE: When conducting accuracy analysis, the DME signal-in-space error can be assumed to be 0.1 NM 95% (both inside and outside the published service volume). If demonstrating accuracy under bench or flight test conditions the actual accuracy of the bench equipment or ground facility should be considered.

2. Accomplishing New Testing. New testing should be performed under the same conditions used to demonstrate compliance with the original TSO-C66 standard.

3. Manufacturers who have demonstrated more accurate DME performance should state the demonstrated accuracy in a letter to their customers. Manufacturers are also requested to provide a copy of this letter to AFS-400 to facilitate making the information available to all operators.

(2) Multi-Sensor Systems (FMS). The manufacturer should review the available data for the integrated navigation system, and obtain additional data as appropriate, to determine compliance with the criteria in this appendix. Manufacturers who have determined compliance should state such in a letter to their customers, along with any operational limitations (for example, if the pilot is expected to manually inhibit the use of facilities which are listed by NOTAM as unavailable). The manufacturer's certification may limit the compliance to specific DME systems, or may reference any DME qualified to the accuracy requirements of TSO-C66C. Manufacturers should also provide a copy of this letter to AFS-400.

(a) FMS accuracy is dependent on a number of factors, including latency effects, the selection of DME facilities, the method of combining information from multiple DMEs, and the effects of other sensors used to determine a position. For FMSs using two (or more) DMEs at the same time and limiting the DME include angle to between 30 and 150°, the accuracy requirement can be met if the DME sensors meet the accuracy requirements of TSO-C66C. For FMSs without these characteristics, the accuracy should be evaluated under poor DME geometry scenarios and should consider the demonstrated DME sensor accuracy. Poor geometry scenarios may include angles at the limits specified earlier, with or without additional DME facilities available outside those conditions.

(b) Identify those conditions that would result in failure to meet the accuracy requirement, and the means to preclude those identified conditions.

APPENDIX 2. BASELINE AREA NAVIGATION (RNAV) SYSTEM CRITERIA FOR DISTANCE MEASURING EQUIPMENT (DME) AND INERTIAL REFERENCE UNIT (IRU) RNAV SYSTEMS

1. PURPOSE.

This appendix defines a minimum (DME/DME/IRU (or abbreviated D/D/I) RNAV system baseline performance. The baseline D/D/I performance standard factors the available infrastructure and accommodates those D/D/I RNAV systems capable of supporting RNAV procedures with track keeping accuracy performance of 2.0 NM (95%) and Standard Instrument Departures (SIDs) and Standard Terminal Arrivals (STARs) as low as 1.0 NM (95%). For routes and procedures designed using this performance standard, the FAA will decide if adequate DME coverage is available using FAA computer modeling and flight inspection assets. This assessment of DME coverage will also determine if an Expanded Service Volume (ESV) is necessary for select DME facilities. These criteria may be applied under an airworthiness approval for new equipment or used by the manufacturer for self-certification of existing equipment.

2. MINIMUM REQUIREMENTS FOR DME/DME/IRU RNAV SYSTEM.

a. Tuning and Updating Position of DME Facilities. The DME/DME/IRU RNAV system must:

(1) Position update within 30 seconds of tuning DME navigation facilities.

(2) Auto-tune multiple DME facilities.

(3) Provide continuous DME/DME Position Updating. (Given a third DME facility or a second pair has been available for at least the previous 30 seconds, there must be no interruption in DME/DME positioning when the RNAV system switches between DME stations/pairs.)

b. Using Facilities in the Airport/Facility Directory. The FAA cannot ensure all DME signals within reception distance of U.S. airspace meet ICAO standards. These could include non-U.S. DME facilities, or Department of Defense (DOD) maintained DME facilities excluded from the National Airspace System (NAS) database. DME/DME RNAV procedure design will only use DME facilities listed in the Airport/Facility Directory (A/FD). Although a procedure design issue, applicants may mitigate this restriction by:

(1) Having the DME/DME RNAV system only use DME facilities listed in the A/FD.

(2) Requiring exclusion of non-NAS DME facilities from the aircraft's navigation database when the RNAV routes or procedures are within reception range of these non-NAS DME facilities.

(3) Demonstrating to the FAA that their RNAV system performs reasonableness checks to detect errors from the non-NAS DME facilities and excludes these facilities from the navigation position solution when appropriate (e.g., using the ARINC 424 coding to preclude tuning co-channel DME facilities when the DME facilities signals-in-space overlap). See paragraph 3 for guidance on testing of reasonableness checks.

c. DME Facility Relative Angles. When needed to generate a DME/DME position, FMS must use, as a minimum, DMEs with a relative include angle between 30° and 150°. The FMS may use DME pairs outside these angles (for example, 20° to 160°).

d. RNAV System Use of DMEs. The RNAV system may use any receivable DME facility (listed in the A/FD) regardless of its location. When needed to generate a DME/DME position, as a minimum, the RNAV system must use an available and valid low altitude and/or high altitude DME anywhere within the following region around the DME facility:

(1) Greater than or equal to 3 NM from the facility; and

(2) Less than 40° above the horizon when viewed from the DME facility; and

(3) For facilities with an ARINC 424 figure of merit (FOM):

If the ARINC 424 FOM is:	**The aircraft's DME/DME RNAV system must be:**	
	Less than or equal to:	**And less than:**
0	40 NM from the facility	12,000 ft above facility elevation
1	70 NM from the facility	18,000 ft above facility elevation
2	130 NM from the facility	--
3	160 NM from the facility	--

NOTE 1: RNAV systems are not required to use the FOM value.

NOTE 2: RNAV routes and procedures may include new FOMs with ESVs.

(4) A valid DME facility:

(a) Broadcasts an accurate facility identifier signal,

(b) Satisfies the minimum field strength requirements, and

(c) Is protected from other interfering DME signals according to the co-channel and adjacent channel requirements.

e. No Requirement to Use VOR, NDB, LOC, or AHRS. There is no requirement to use VOR (VHF omni-range), NDB (non-directional beacon), LOC (localizer), or AHRS (attitude heading reference system) during normal operation of the DME/DME/IRU RNAV system.

f. Position Estimation Accuracy. Given any two DME facilities satisfying the criteria in subparagraphs 2b, 2c, and 2d, and any combination of other valid DME facilities not meeting that criteria, the 95% position estimation accuracy must be better than or equal to 0.4 NM.

NOTE: In order to take full advantage of the inertial coasting capability during gaps in DME/DME coverage, it is necessary to define the best possible baseline for the DME/DME performance at the beginning of the coverage gap. This baseline needs to take into account the DME geometry and performance at that time to provide as much margin as possible, thereby allowing the most time for INS coasting. This equation assumes the airborne equipment satisfies the accuracy requirements of TSO-C66C.

g. Preventing Erroneous Guidance from Co-Channel Facilities. The RNAV system must ensure co-channel DME facilities do not cause erroneous guidance. This could be accomplished by including reasonableness checking when initially tuning a DME facility or excluding a DME facility when there is a co-channel DME within line-of-sight. See paragraph 3 for guidance on testing of reasonableness checks.

NOTE: The DME assessment cannot use a DME facility when there is a co-channel DME facility within line-of-sight.

h. Preventing Erroneous VOR Signals-in-Space. The RNAV system must ensure an erroneous VOR signal-in-space does not affect the position accuracy. This may be accomplished by excluding VOR signals or weighting and/or monitoring the VOR signal with DME/DME to ensure it does not mislead position results (for example, through reasonableness checks). See paragraph 3 for guidance on testing of reasonableness checks.

i. Ensuring RNAV Systems Use Operational Facilities. The RNAV system must use operational DME facilities. DME facilities listed by NOTAM as unavailable (for example, under test or other maintenance) could still reply to an airborne interrogation. (Therefore, non-operational facilities must not be used.) An FMS may exclude non-operational facilities by checking the identification or inhibiting the use of facilities identified as not operational.

j. Inertial Performance.

(1) Inertial system performance must satisfy the criteria of 14 CFR Part 121, Appendix G.

(2) Automatic position updating capability from the DME/DME solution is required.

NOTE: Operators/pilots should contact manufacturers to discern if any annunciation of inertial coasting is suppressed following loss of radio updating.

(3) The system must be able to accept a position update immediately prior to takeoff. Immediately prior to takeoff, the pilot should confirm the aircraft's inertial position within 1,000 feet (0.17 NM) of a known position.

NOTE: Based on an evaluation of IRU performance, the growth in position error after reverting to IRU can be expected to be less than 2 NM per 15 minutes.

(4) Pilots must use a CDI/flight director and/or autopilot in lateral navigation mode. Other methods providing an equivalent level of performance may be acceptable.

(5) The system must exclude VORs greater than 40 NM from the aircraft.

NOTE: Some aircraft systems revert to VOR/DME-based navigation before reverting to inertial coasting.

k. Operational Mitigations. Operational mitigations defined to qualify equipment with this AC will not require pilot action during critical phases of flight, pilot monitoring of the RNAV system's navigation updating source(s), or time intensive programming/ blackballing of multiple DME stations prior to executing a procedure.

NOTE 1: Blackballing single facilities listed by NOTAM as out-of-service and/or programming route/procedure-defined "critical" DME is acceptable when this mitigation requires no pilot action during a critical phase of flight. A programming requirement also does not imply the pilot should complete manual entry of DME facilities which are not in the navigation database. Instead, this allows RNAV systems to tune a critical DME, as appropriate, to a specific route or procedure.

NOTE 2: The critical phase of flight is normally from the final approach fix on an approach procedure through missed approach, or from field elevation to 2,500 ft above airport elevation on a departure.

l. Minimum Performance Standard for each Route or Procedure. The track keeping accuracy must be less than or equal to 1.0 NM (95%) throughout the route. In order to maximize the amount of IRU coasting allowed, the flight technical error for D/D/I aircraft on terminal procedures should be limited to 0.5 NM (95%).

NOTE: The FAA assures that systems meeting the D/D/I RNAV minimum performance standard satisfy this requirement on all identified routes and procedures, and these RNAV systems do not require further evaluation. Systems seeking approval using different RNAV system characteristics or performance must demonstrate this performance for each published route or procedure.

3. REASONABLENESS CHECKS. Many FMSs perform a reasonableness check to verify valid DME measurements. Reasonableness checks are very effective against database errors or erroneous system acquisition (such as co-channel facilities), and typically fall into two classes:

- Those the FMS uses after it acquires a new DME. The FMS compares the aircraft's position before using the DME to the aircraft's range to the DME, and

- Those the FMS continuously uses, based on redundant information (for example, extra DME signals or IRU data).

a. General Requirements. The reasonableness checks are intended to prevent navigation aids from being used for navigation update in areas where the data can lead to radio position fixing errors due to co-channel interference, multipath, and direct signal screening. In lieu of using radio navigation aid published service volume, the navigation system should provide checks, which preclude use of duplicate frequency NAVAIDs within range, over-the-horizon NAVAIDs, and use of NAVAIDs with poor geometry.

b. Assumptions. Reasonableness checks can be susceptible to conditions that obviate their utility against the requirements in this document.

(1) Do not assume a DME signal remains valid just because it was valid when acquired.

(2) Do not assume extra DME signals are available. The intent of this baseline is to support operations where the infrastructure is minimal (for example, when only two DMEs are available for parts of the procedure).

c. Use Stressing Conditions to Test Effectiveness. When an applicant uses a reasonableness check to satisfy any requirement in this AC, he/she must test the effectiveness of the check under stressing conditions. An example of this condition is a DME signal that is valid at acquisition and ramps off during the test (similar to what a facility under test might do), when there is only one other supporting DME or two signals of equal strength.

4. PERFORMANCE CONFIRMATION PROCESS.

New systems may demonstrate compliance with these criteria as part of the airworthiness approval. For existing systems, the manufacturer should determine compliance with the equipment and aircraft criteria in this appendix. Manufacturers who have achieved their compliance should provide this information by letter to their customers. Operators/pilots may use this approval as a basis for their operations. Manufacturers are also requested to provide a copy of this letter to Flight Technologies and Procedures Division, AFS-400, (202) 385-4586, to facilitate making the information available to all operators. Guidance is provided below for both an airplane manufacturer and FMS and DME manufacturers.

a. Airplane Manufacturer (Type Certificate (TC) holders incorporating FMS and DME/DME positioning). The manufacturer should review the available data for the integrated navigation system and obtain additional data, as appropriate, to determine compliance with the criteria in this AC. Those manufacturers who have achieved compliance with the criteria should provide this information by letter to their customers. Manufacturers are also requested to provide a copy of this letter to AFS-400 to facilitate making the information available to all operators.

b. Equipment manufacturers (typically separate Technical Standard Order (TSO) DME and FMS holders).

(1) DME Sensor. The only requirement in this appendix that needs to be considered for a DME sensor is the accuracy requirement. DME sensors have been demonstrated to a variety of performance requirements per TSO-C66, Distance Measuring Equipment (DME) operating within the Radio Frequency Range of 960-1215 Megahertz.

(a) TSO-C66 performance standards have evolved as follows:

1. TSO-C66: (Aug 1960) RTCA/DO99.

2. TSO-C66A: (Sep 1965) RTCA/DO151, accuracy requirement as total error with 0.1 NM attributed to ground facility, airborne equipment accuracy of 0.5 NM, or 3% of distance, whichever is greater, with a maximum of 3 NM.

3. TSO-C66B: (Nov 1978) RTCA/DO151a, accuracy requirement as total error with 0.1 NM attributed to ground facility, airborne equipment accuracy of 0.5 NM, or 1% of distance, whichever is greater, with a maximum of 3 NM.

4. TSO-C66C: (Sept 1985) RTCA/DO189, accuracy requirement as total error for the airborne equipment of 0.17 NM or 0.25% of distance, whichever is greater.

(b) The accuracy required by TSO-C66C is adequate to support the criteria in this appendix, and DME equipment manufacturers under these versions of the TSO do not need to further evaluate their equipment for Type A operations. DME sensor manufacturers may use the following process to establish more accurate performance than originally credited.

1. Determining Achieved Accuracy: Rather than relying on original demonstrated performance, the applicant may elect to review the original TSO or TC/STC test data to determine the demonstrated accuracy and/or make any appropriate changes to qualification tests to determine achieved accuracy.

NOTE: When conducting accuracy analysis, the DME signal-in-space error can be assumed to be 0.1 NM 95% (both inside and outside the published service volume). If demonstrating accuracy under bench or flight test conditions the actual accuracy of the bench equipment or ground facility should be considered.

2. Accomplishing New Testing. New testing should be performed under the same conditions used to demonstrate compliance with the original TSO-C66 standard.

3. Manufacturers who have demonstrated more accurate DME performance should state the demonstrated accuracy in a letter to their customers. Manufacturers are also requested to provide a copy of this letter to AFS-400 to facilitate making the information available to all operators.

(2) Multi-Sensor Systems (FMS). The manufacturer should review the available data for the integrated navigation system, and obtain additional data, as appropriate, to determine compliance with the criteria in this appendix. Manufacturers who have determined compliance should state as such in a letter to their customers, along with any operational limitations (for example, if the pilot is expected to manually inhibit the use of facilities which are listed by NOTAM as unavailable). The manufacturer's certification may limit the compliance to specific DME systems, or may reference any DME qualified to the accuracy requirements of TSO-C66C. Manufacturers should also provide a copy of this letter to AFS-400.

(a) FMS accuracy is dependent on a number of factors, including latency effects, the selection of DME facilities, the method of combining information from multiple DMEs, and the effects of other sensors used to determine a position. For FMSs using two (or more) DMEs at the same time and limiting the DME include angle to between 30 and 150°, the accuracy requirement can be met if the DME sensors meet the accuracy requirements of TSO-C66C. For FMSs without these characteristics, the accuracy should be evaluated under poor DME geometry scenarios and should consider the demonstrated DME sensor accuracy. Poor geometry scenarios may include angles at the limits specified earlier, with or without additional DME facilities available outside those conditions.

(b) Identify those conditions that would result in failure to meet the accuracy requirement, and the means to preclude those identified conditions.