U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: U.S. Terminal and En Route Area Navigation (RNAV) Operations

Date: 4/14/15

Initiated by: AFS-400

AC No: 90-100A

Change: 2

1. PURPOSE. This advisory circular (AC) provides operational and airworthiness guidance for operation on U.S. Area Navigation (RNAV) routes, instrument departure procedures (DPs), and Standard Terminal Arrivals (STAR). Operators and pilots should use the guidance in this AC to determine their eligibility for these U.S. RNAV routes and procedures. In lieu of following this guidance without deviation, operators may elect to follow an alternative method, provided the alternative method is found to be acceptable by the Federal Aviation Administration (FAA). For the purpose of this AC, “compliance” means meeting operational and functional performance criteria. Mandatory terms in this AC such as “must” are used only to ensure applicability of these particular methods of compliance when the acceptable means of compliance described are used. This AC does not change, add, or delete regulatory requirements or authorize deviations from regulatory requirements.

2. PRINCIPAL CHANGES. This change updates the RAIM Web site information to direct all users of www.raimprediction.net to now use the Service Availability Prediction Tool (SAPT) Web site.

PAGE CONTROL CHART

Remove Pages	Dated	Insert Pages	Dated
Page 11	3/1/07	Page 11	4/14/15

John Barbagallo
Deputy Director, Flight Standards Service

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: U.S. Terminal and En Route Area Navigation (RNAV) Operations

Date: 8/4/14

Initiated by: AFS-400

AC No: 90-100A

Change: 1

1. PURPOSE. This advisory circular (AC) provides operational and airworthiness guidance for operation on U.S. Area Navigation (RNAV) routes, Instrument Departure Procedures (DPs), and Standard Terminal Arrivals (STARs). Operators and pilots should use the guidance in this AC to determine their eligibility for these U.S. RNAV routes and procedures. In lieu of following this guidance without deviation, operators may elect to follow an alternative method, provided the alternative method is found to be acceptable by the Federal Aviation Administration (FAA). For the purpose of this AC, “compliance” means meeting operational and functional performance criteria. Mandatory terms in this AC such as “must” are used only to ensure applicability of these particular methods of compliance when the acceptable means of compliance described are used. This AC does not change, add, or delete regulatory requirements or authorize deviations from regulatory requirements.

2. PRINCIPAL CHANGES. This change updates the division and Web site address in subparagraph 9c1)b) to reflect the new location of the compliance table link on the AFS-470 website, where pilots and operators can confirm the capability of their equipment.

PAGE CONTROL CHART

Remove Pages	Dated	Insert Pages	Dated
Page 10	3/1/07	Page 10	8/4/14

John Barbagallo
Acting Deputy Director, Flight Standards Service

U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: U.S. Terminal and En Route Area Navigation (RNAV) Operations

Date: 3/1/07

Initiated by: AFS-400

AC No: 90-100A

Change:

1. PURPOSE.

a. This advisory circular (AC) provides operational and airworthiness guidance for operation on U.S. Area Navigation (RNAV) routes, instrument departure procedures (DPs), and Standard Terminal Arrivals (STAR). Operators and pilots should use the guidance in this AC to determine their eligibility for these U.S. RNAV routes and procedures. In lieu of following this guidance without deviation, operators may elect to follow an alternative method, provided the alternative method is found to be acceptable by the Federal Aviation Administration (FAA). For the purpose of this AC, "compliance" means meeting operational and functional performance criteria. Mandatory terms in this AC such as "must" are used only to ensure applicability of these particular methods of compliance when the acceptable means of compliance described are used. This AC does not change, add, or delete regulatory requirements or authorize deviations from regulatory requirements.

NOTE: 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. Applicability of AC 90-100A. AC 90-100A applies to operation on U.S. Area Navigation (RNAV) routes (Q-routes and T-routes), departure procedures (Obstacle Departure Procedures and Standard Instrument Departures), and Standard Terminal Arrivals (STAR). It does not apply to over water RNAV routes (refer to 14 CFR part 91, § 91.511, including the Q-routes in the Gulf of Mexico and the Atlantic routes) or Alaska VOR/DME RNAV routes ("JxxxR"). It does not apply to off-route RNAV operations, Alaska GPS routes or Caribbean routes, or helicopter operations involving offshore or specific heliport procedures.

c. 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.

d. Background. This criterion is consistent with the ICAO guidance material for the implementation of area navigation (RNAV 1 and RNAV 2) operations. AC 90-100 became effective 7 January 2005. Since then, ICAO has continued to harmonize area navigation

(RNAV) performance criteria. AC 90-100A reflects these harmonized ICAO performance-based navigation criteria as well as lessons learned from the initial U.S. RNAV implementation.

e. Structure. After the initial paragraphs which include Terminology and References, this AC is structured as follows:

- General Information (paragraph 6).
- RNAV System Eligibility (paragraph 7).
- RNAV System Approval Process (paragraph 8).
- Operator Approval Process (paragraph 9).
- Flightcrew Operating Procedures (paragraph 10).
- Pilot Knowledge Requirements and Training (paragraph 11).
- Criteria for RNAV Systems Using DME (Appendix 1).
- Criteria for RNAV Systems Using DME and Inertial (Appendix 2).
- Criteria for RNAV System Functionality (Appendix 3).

2. CANCELLATION. Advisory Circular 90-100, U.S. Terminal and En Route Area Navigation (RNAV) Operations, dated January 7, 2005, is canceled.

3. RELATED CODE OF FEDERAL REGULATIONS SECTIONS. Title 14 of the Code of Federal Regulations (14 CFR) part 91, §§ 91.123 and 91.205; part 95; part 121, § 121.349; part 125, § 125.203; part 129, § 129.17; and part 135, § 135.165.

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

a. Aircraft-Based Augmentation System (ABAS). A system augmenting and/or integrating information obtained from other GNSS elements with information on board the aircraft. The most common form of ABAS is receiver autonomous integrity monitoring (RAIM).

b. Area Navigation (RNAV). 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, the specified RNAV accuracy must be met 95 percent of the flight time.

(1) RNAV 1 requires a total system error of not more than 1 NM for 95 percent of the total flight time.

(2) RNAV 2 requires a total system error of not more than 2 NM for 95 percent of the total flight time.

c. Area Navigation (RNAV) System. This AC only addresses RNAV systems using positioning inputs from GPS/GNSS and DME, and IRU. Criteria for RNAV systems are discussed in appendix 1 and 2. Criteria for RNAV system functionality is discussed in appendix 3.

d. Critical DME. A DME facility that, when unavailable, results in navigation service which is insufficient for DME/DME/IRU supported 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 DPs and STARs may be published with only two DMEs, in which case, both are critical.

e. DME/DME (D/D) RNAV. Refers to navigation using DME ranging from at least two DME facilities to determine position.

f. DME/DME/Inertial (D/D/I) RNAV. Refers to navigation using DME ranging from at least two DME facilities to determine position along with use of an inertial reference unit (IRU) to provide sufficient position information during limited DME gaps.

g. Flight Technical Error (FTE). Accuracy with which an aircraft is controlled, as measured by the indicated aircraft position with respect to the indicated command or desired position. It does not include procedural blunder errors.

h. 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.

i. 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.

j. Position Estimation Error (PEE). Difference between true position and estimated position.

k. 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.

l. RNAV Procedure. An RNAV Instrument Departure Procedure or RNAV Standard Terminal Arrival.

(1) Instrument Departure Procedure. A DP is a published IFR procedure providing obstruction clearance from the terminal area to the en route structure. There are two types of DPs: Standard Instrument Departures (SIDs) and Obstacle Departure Procedures (ODPs).

(i) Standard Instrument Departure (SID). A SID is a published IFR air traffic control (ATC) departure procedure providing obstacle clearance and a transition from the terminal area to the en route structure. SIDs are primarily designed for air traffic system enhancement to expedite traffic flow and to reduce pilot/controller workload.

(ii) Obstacle Departure Procedure (ODP). A preplanned instrument flight rule (IFR) departure procedure printed for pilot use in textual or graphic form to provide obstruction clearance via the least onerous route from the terminal area to the appropriate en route structure. ODPs are recommended for obstruction clearance and may be flown without ATC clearance unless an alternate departure procedure (SID or radar vector) has been specifically assigned by ATC.

(2) Standard Terminal Arrival (STAR). A STAR is a published IFR ATC arrival procedure that provides a transition from the en route structure to the terminal area. STARs may include one or more runway transitions providing guidance to either a standard instrument approach procedure or a point in space from which radar vectors are provided by ATC.

m. RNAV Route. An RNAV route (“Q” or “T”), within the high or low altitude structure of the Contiguous United States, requiring system performance by GPS/GNSS or DME/DME/IRU RNAV systems, as required.

n. Total System Error. The difference between the true position and the desired position. This error is equal to the vector sum of the path steering error, path definition error, and PEE.

5. REFERENCES.

(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. Advisory Circular (AC) 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors.

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

h. AC 20-153, Acceptance of Data Processes and Associated Navigation Databases.

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

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

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

l. 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.

m. 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).

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

o. 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.

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

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

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

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

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

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

6. GENERAL INFORMATION ON RNAV 1 AND RNAV 2 OPERATIONS.

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

(1) Relies on normal descent profiles and identifies minimum segment 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, DPs, 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), Pilot's Operating Handbook (POH), or the operating manual for their avionics;

(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 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.

(1) DME signals are considered to meet signal-in-space accuracy tolerances everywhere the signals are received.

(2) For RNAV operations where reliance is placed upon the IRU, some aircraft systems temporarily revert to VOR/DME-based navigation before reverting to inertial coasting. When the VOR is within 40 NM from the route/procedure and there is insufficient DME/DME navigation infrastructure, the impact of VOR radial accuracy has been evaluated by the FAA and determined to not affect aircraft position accuracy.

(3) The available navigation infrastructure supporting the procedure will be clearly designated on all appropriate charts (for example, GPS or DME/DME/IRU).

(4) The FAA will monitor the navigation infrastructure and issue timely warnings of outages (NOTAM).

(5) The navigation standard (for example, RNAV 1 or RNAV 2) required for all RNAV procedures/routes will be clearly designated on all appropriate charts. However, SIDs, ODPs, and STARs will be flown with RNAV 1 procedures.

(6) All routes and procedures referenced in this AC are intended to be flown by DME/DME/IRU and/or GPS/GNSS equipped aircraft meeting the performance requirements in this AC.

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

d. Unless the RNAV route, DP, or STAR specifically requires GPS or GNSS equipage, aircraft on the RNAV route, DP, 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, DPs, and STARs comply with applicable ICAO standards.

f. All routes/procedures must be based upon WGS 84 coordinates.

g. The navigation data published for the routes, procedures and supporting navigation aids must meet the requirements of ICAO Annex 15.

7. RNAV SYSTEM ELIGIBILITY.

a. Aircraft with a statement of compliance to this AC in their Airplane Flight Manual (AFM), Pilot's 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 many of the requirements defined in this AC. Such equipment still requires evaluation by the manufacturer against all the functional and performance requirements in 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 deviating from the functionality described in Appendix 3 of this document) installed for IFR use IAW AC 20-138 or AC 20-138A.

(4) Aircraft with TSO-C146a (without deviating from the functionality described in Appendix 3 of this document) installed for IFR use IAW AC 20-138A.

NOTE: Refer to paragraph 5 for TSO and AC references.

d. Aircraft with a statement from the manufacturer documenting compliance with the criteria in this AC (appendix 1 or 2, as applicable, and appendix 3) meet the performance and functional requirements of this AC. These statements should include the airworthiness basis for compliance. Compliance with the sensor requirements in paragraph 8 will have to be determined by the equipment or aircraft manufacturer, while compliance with the functional requirements in Appendix 3 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/IRU-based procedures, 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 may not meet all 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. RNAV SYSTEM APPROVAL PROCESS.

a. Navigation System Accuracy. The navigation system accuracy is dependent on the total system error, defined in paragraph 4 of this AC.

(1) RNAV Routes: Aircraft operating on RNAV routes must maintain a total system error bounded by the RNAV value for 95 percent of the total flight time. A Flight Technical Error (FTE) of 1.0 NM (95 percent) is acceptable for RNAV 2 operations. RNAV 2 will be used for en route unless otherwise specified.

(2) RNAV 1 DPs and STARs. Aircraft operating on RNAV 1 DPs and STARs must maintain a total system error of not more than 1 NM for 95 percent of the total flight time. An FTE of 0.5 NM (95 percent) is acceptable for RNAV 1 operations. RNAV 1 will appear on all RNAV SID and STAR charts.

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).

(1) Global Navigation Satellite System (GNSS) in accordance with TSO-C145a, TSO-C146a, and TSO-C129/C129a. Positioning data from other types of navigation sensors may be integrated with the GNSS data provided it does not cause position errors exceeding the total system error requirements. The use of GPS equipment approved to TSO-C129() is limited to those which include the minimum system functions specified in Appendix 3. As a minimum, integrity should be provided by ABAS. In addition, GPS stand-alone equipment should include the following additional functions:

- Pseudorange step detection, and
- Health word checking.

For procedures requiring GPS and/or aircraft approvals requiring GPS, if the navigation system does not automatically alert the flightcrew of a loss of GPS, the operator must develop procedures to verify correct GPS operation.

(2) DME/DME RNAV equipment complying with the criteria in appendix 1. Based on current DME availability evaluations, coverage is not sufficient to support DME/DME RNAV operations without additional IRU augmentation or using GPS.

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

NOTE: LORAN-C criteria have not been developed.

c. Functional criteria listed in Appendix 3. The requirements of Appendix 3 help ensure aircraft RNAV system performance meets procedure design criteria.

9. OPERATOR APPROVAL PROCESS.

a. Background. This section identifies the operational requirements for RNAV 2 and RNAV 1 operations. Performance requirements must be met. However, the approval process depends on the operating rules for the particular operation (e.g., part 91 versus part 121).

b. After Completing the Following Steps. An RNAV operational approval or appropriate operations specifications/management specifications (OpSpecs/MSpecs), should then be issued by the FAA before conducting RNAV operations. Part 91 operators (excluding subpart K) meeting the RNAV performance requirements in this AC should follow the aircraft and training guidance in this AC, but are not required to obtain a Letter of Authorization (LOA).

(1) Aircraft equipment eligibility must be determined and documented;

(2) Operating procedures for the navigation systems to be used and the operator navigation database process must be documented;

(3) Flightcrew training based upon the operating procedures must be documented;

(4) The above material must be accepted by the FAA; and operational approval should then be obtained in accordance with operating rules.

c. Documentation for Conducting RNAV Operations.

(1) Aircraft Eligibility.

(a) Description of aircraft equipment. The operator must have a configuration list detailing pertinent components and equipment to be used for RNAV 2/RNAV 1.

(b) Eligibility airworthiness documents. Relevant documentation acceptable to the FAA must be available to establish that the aircraft is equipped with RNAV systems meeting RNAV 2/RNAV 1 requirements. Manufacturers evaluate their systems against these criteria, and a current list of compliant equipment can be found at the AFS-470 Web site (applicable to all operators): http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afs/afs400/afs470/pbn/. Pilots and operators can confirm the capability of their equipment on this list, or obtain equipment performance information from the relevant aircraft and avionics manufacturer.

(2) Training Documentation.

(a) Part 91K, 121, 125, 129 and 135 operators should have a training program addressing the operational practices, procedures and training items identified in paragraph 11 of this AC (e.g., initial, upgrade or recurrent training for flightcrew, dispatchers or maintenance personnel).

NOTE: It is not required to establish a separate training program or regimen if RNAV training in paragraph 11 is already an integrated element of a training program.

(b) Part 91 operators should be familiar with the practices and procedures identified in paragraph 11, Pilot Knowledge Requirements and Training.

(3) Operations Manuals and Checklists.

(a) Operations manuals and checklists for commercial operators must address information/guidance on the standard operating procedures detailed in paragraph 10 of this AC. The appropriate manuals should contain navigation operating instructions and contingency procedures where specified. Manuals and checklists must be submitted for review as part of the application process.

(b) Private operators should operate using the practices and procedures identified in paragraph 11, Pilot Knowledge Requirements and Training.

(4) Maintenance Considerations.

(a) Any minimum equipment list (MEL) revisions necessary to address RNAV provisions must be approved.

(b) If an RNAV operational approval is granted on the basis of a specific operational procedure, operators must modify the MEL, or equivalent, and specify the required dispatch conditions.

NOTE: Since this may constitute a special operation, it is not intended to require MEL requirements for each aspect of RNAV operations.

(c) Parts 91K, 121, 125, 129, and 135 operators should have an approved maintenance program.

10. U.S. RNAV FLIGHTCREW OPERATING PROCEDURES. Pilots should be familiar with the normal operating and contingency procedures associated with U.S. RNAV routes, DPs, and STARs.

a. Pre-flight Planning.

(1) Operators and pilots intending to conduct operations on U.S. RNAV routes, DPs, 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) NOTAMs should be checked to verify the health of critical DMEs for navigation relying on DME. Pilots should assess their capability to navigate (potentially to an alternate destination) in case of failure of critical DME while airborne.

(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. RNAV STAR procedures may be designed using multiple runway transitions. Operators not having this functionality shall provide an acceptable alternative means (for example, a tailored navigation data base). If no equivalent means are available to fly the charted RNAV procedure containing multiple runway transitions, operators will not file or accept clearance for these procedures.

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 affecting navigation data is published for the procedure, the database must not be used to conduct the procedure.

(4) If not equipped with GPS/GNSS, aircraft must be capable of navigation system updating using DME/DME/IRU for RNAV 2 or RNAV 1 routes, as well as RNAV 1 departure procedures (DPs) and Standard Terminal Arrivals (STAR). As stated in paragraph 8.b.(1), if the navigation system does not automatically alert the flightcrew of a loss of GPS/GNSS, the operator must develop procedures to verify correct GPS/GNSS operation.

(5) If TSO-C129 equipment is used to solely satisfy the RNAV requirement, GPS RAIM availability must be confirmed for the intended route of flight (route and time) using current GPS satellite information. The availability of SBAS or ABAS fault detection can be determined through NOTAMs (if available) or through prediction for the intended RNAV 1 or RNAV 2 operation. Operators may choose to monitor the status of each satellite in its plane/slot position, account for the latest GPS constellation NOTAMs, and compute RAIM availability using model-specific RAIM prediction software, or by using the Service Availability Prediction Tool (SAPT) on the FAA en route and terminal RAIM prediction Web site, or by contacting a Flight Service Station (FSS). Receiver RAIM prediction capability can also be used. 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. Pilots should assess their capability to navigate (potentially to an alternate destination) in case of failure of GPS navigation.

(6) If TSO-C145/C146 equipment is used to satisfy the RNAV requirement, the pilot/ operator need not perform the prediction if WAAS coverage is confirmed to be available along the entire route of flight.

NOTE: Outside the U.S. or in areas where WAAS coverage is not available, operators using TSO-C145/C146 receivers are required to check GPS RAIM availability.

(7) Proper Interpretation of Pre-Departure Clearance (PDC) and printed routings. Pilots of operators using PDC and printed routings must be able to properly interpret their assigned clearance. Specifically, pilots must be able to recognize direct routings, assigned altitudes, revised clearances, SIDs, and en route transitions. Pilots must understand their operator's PDC notation and must request clarification from ATC if any doubt exists with regard to their clearance.

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.

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

(3) RNAV DPs and STAR procedures must be retrieved by procedure name from the onboard navigation database and conform to the charted procedure.

(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 from the database 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/GNSS avionics to meet the requirements of this AC to fly RNAV routes.

(5) Manual entry of waypoints using latitude/longitude or place/bearing is not permitted. Additionally, pilots must not change any RNAV DP or STAR database waypoint type from a fly-by to a fly-over or vice versa.

(6) Flightcrews 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.

(7) Verification of assigned route and correct entry of transitions into RNAV System/Flight Management System (FMS).

(a) DPs. Prior to flight, pilots must verify their aircraft navigation system is operating correctly and the correct <u>runway</u> and departure procedure (<u>including</u> any applicable en route transition) are entered and properly depicted. Pilots who are assigned an RNAV departure procedure and subsequently receive a change of runway, procedure or transition must verify the appropriate changes are entered and available for navigation prior to takeoff. A final check of proper runway entry and correct route depiction, shortly before takeoff, is recommended.

(b) Routes. Pilots must verify proper entry of their ATC assigned route upon initial clearance and any subsequent change of route. Pilots must ensure the waypoints sequence depicted by their navigation system matches the route depicted on the appropriate chart(s) and their assigned route.

(c) STARs. Pilots must verify their aircraft navigation system is operating correctly and the correct arrival procedure and runway (including any applicable transition) are entered and properly depicted.

(8) Use of navigation map displays. Prior to takeoff, pilots of aircraft with a navigation map display should verify the relationship of the aircraft position symbol to their assigned runway (if available) and route on their display matches external visual cues, as well as charts. Specifically, once on or near their assigned runway, pilots should ensure their navigation display reflects the same relative position to the runway and the route depiction reflects that of the respective chart. During flight, these displays should be used in concert with textual displays for route verification.

(9) Pilots must use a lateral deviation indicator (or equivalent navigation map display), flight director and/or autopilot in lateral navigation mode on RNAV 1 routes. Pilots are encouraged to use a lateral deviation indicator (or equivalent navigation map display), flight director and/or autopilot in lateral navigation mode on RNAV 2 routes. Pilots of aircraft with a lateral deviation indicator (e.g., a standalone GNSS receiver) must ensure that lateral deviation indicator scaling (full-scale deflection) is suitable for the navigation accuracy associated with the route/procedure (i.e., ±1 nm for RNAV 1, ± 2.0 nm for RNAV 2).

NOTE: Some TSO-C129() equipment automatically goes to ±5.0 NM beyond 30 NM from the airport reference point. This is acceptable provided the pilot maintains the required minimum performance standard associated with the procedure.

All pilots are expected to maintain route centerlines, as depicted by onboard lateral deviation indicators and/or flight guidance during all RNAV operations described in this AC unless authorized to deviate by ATC or under emergency conditions. For normal operations, cross-track error/deviation (the difference between the RNAV system computed path and the aircraft position relative to the path) should be limited to ± ½ the navigation accuracy associated with the procedure or route (i.e., 0.5 nm for RNAV 1, 1.0 nm for RNAV 2). Brief deviations from this standard (e.g., overshoots or undershoots) during and immediately after procedure/route turns, up to a maximum of 1 times the navigation accuracy (i.e., 1.0 nm for RNAV 1, 2.0 nm for RNAV 2), are allowable.

NOTE: Some aircraft do not display or compute a path during turns. As such, pilots of these aircraft may not be able to adhere to the ± ½ lateral navigation *accuracy during procedural/route turns but are still expected to satisfy the standard during intercepts following turns and on straight segments.*

(10) 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 8.a.) does not apply.

(11) Manually selecting aircraft bank limiting functions may reduce the aircraft's ability to maintain its desired track and are not recommended. Pilots should recognize manually selectable aircraft bank-limiting functions might reduce their ability to satisfy ATC path expectations, especially when executing large angle turns. This should not be construed as a requirement to deviate from AFM procedures; rather, pilots should be encouraged to limit the selection of such functions within accepted procedures.

(12) DPs and STARs are flown as RNAV 1 procedures. RNAV routes are flown as RNAV 2 unless otherwise specified.

(13) Pilots operating RNP-approved aircraft under the provisions of this AC are not required to modify manufacturer's RNP default values established in the Flight Management Computers.

c. RNAV DP and STAR Specific Requirements.

(1) RNAV DP Engagement Altitudes. For DPs, the pilot must be able to engage RNAV equipment to follow flight guidance for lateral RNAV no later than 500 feet above airport elevation.

(2) Pilots must use a lateral deviation indicator (or equivalent navigation map display), flight director and/or autopilot in lateral navigation mode on RNAV 1 routes. The full-scale CDI deflection value of ±1 NM is acceptable.

(3) DME/DME/IRU (D/D/I) Aircraft. Pilots of aircraft without GPS/GNSS, 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: For aircraft using TSO-C129/C129a, the departure airport must be loaded into the flight plan in order to achieve the appropriate navigation system monitoring and sensitivity. For aircraft using TSO-C145a/C146a avionics, if the departure begins at a runway waypoint, then the departure airport does not need to be in the flight plan to obtain appropriate 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 ATC as soon as possible. For example, ". . .N1234, failure of GPS/GNSS 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, but are not limited to, loss of autopilot/flight director (if required), or reversion to navigation other than GNSS or DME/DME/IRU (even though no pilot monitoring of navigation updating source is required). In the event of communications failure, established lost communication procedures should be followed.

11. 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. Training need not be repeated if it addresses specific items listed below.

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 Appendix 3 and any other types used by the operator) as well as associated aircraft flight paths.

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

(3) Phraseology. Some RNAV procedures may incorporate the use of "Descend via" clearances. Pilots should be familiar with the correct use of the terminology and procedures as mentioned in AIM (refer to Air Traffic Procedures, Arrival Procedures).

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 flightcrew 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, GPS/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 DP or STAR with appropriate transition.

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

(6) Make a runway change associated with a DP 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/clear route discontinuity.

(15) Remove and reselect navigation sensor input(s).

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

(17) Insert and delete a lateral offset.

(18) Change the arrival airport and alternate airport.

(19) Insert and delete a holding pattern.

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

g. Contingency procedures for RNAV failures.

APPENDIX 1. CRITERIA FOR APPROVAL OF BASELINE AREA NAVIGATION (RNAV) SYSTEMS USING 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 1 and RNAV 2 routes, as well as RNAV 1 departure procedures (DPs) and Standard Terminal Arrivals (STAR). 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 Appendix 1, paragraph 3 for guidance on testing of reasonableness checks.

c. DME Facility Relative Angles. When needed to generate a DME/DME position, the DME/DME RNAV system (referred to as FMS hereafter) 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;

(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), the RNAV system may use the FOM value as the acceptable, usable region:

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 from the facility	--

NOTE 1: RNAV systems may use additional DME facilities (for example, a LOC DME facility may be used but is not required to be used for positioning). 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 Error (PEE). A minimum of two DME facilities satisfying the criteria in paragraph 2, and any other valid DME facilities not meeting that criteria, the 95 percent PEE must be better than or equal to 1.75 NM. A flight technical error contribution not exceeding 1.0 NM (95 percent) may be assumed for RNAV 2 operations.

NOTE 1: 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 percent.

NOTE 2: When using a minimum of two DME facilities satisfying the criteria in appendix 3, paragraph 2.d., the 95 percent PEE must be better than or equal to the following equation:

$$2\sigma_{DME/DME} \leq 2\frac{\sqrt{(\sigma^2_{1,air}+\sigma^2_{1,sis})+(\sigma^2_{2,air}+\sigma^2_{2,sis})}}{\sin(\alpha)}$$

Single facility reference, where: σ_{sis} *= 0.05 NM*
σ_{air} *is MAX {(0.085 NM, (0.125% of distance)}*
α *= inclusion angle (30º to 150º)*

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 appendix 3, 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 for RNAV 2 and 0.87 NM for RNAV 1. 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 RNAV system 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 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) 267-8790, 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:

(i) TSO-C66: (August 1960) RTCA/DO99.

(ii) TSO-C66a: (September 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 percent of distance, whichever is greater, with a maximum of 3 NM.

(iii) TSO-C66b: (November 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 percent of distance, whichever is greater, with a maximum of 3 NM.

(iv) TSO-C66c: (September 1985) RTCA/DO189, accuracy requirement as total error for the airborne equipment of 0.17 NM or 0.25 percent 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 RNAV 1 and RNAV 2 operations. DME sensor manufacturers may use the following process to establish more accurate performance than originally credited.

(i) 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 percent (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.

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

(iii) 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. CRITERIA FOR APPROVAL OF BASELINE AREA NAVIGATION (RNAV) SYSTEMS USING DISTANCE MEASURING EQUIPMENT (DME) AND INERTIAL REFERENCE UNIT (IRU)

1. PURPOSE. This appendix defines a minimum DME/DME/IRU (D/D/I) RNAV system baseline performance capable of supporting RNAV 1 and RNAV 2 routes, as well as RNAV 1 departure procedures (DPs) and Standard Terminal Arrivals (STAR). 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.

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

a. The Minimum Requirements of Appendix 1 Apply and Are Not Repeated in Appendix 2, Except Where Additional Performance Is Required. The performance confirmation process in appendix 1, paragraph 4, applies to appendix 2.

b. 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.

c. Position Estimation Error (PEE). Given any two DME facilities satisfying the criteria in appendix 1, subparagraphs 2b, 2c, and 2d, and any combination of other valid DME facilities not meeting that criteria, the 95 percent PEE must be better than or equal to the value obtained using the equation referenced in Appendix 1, subparagraph 2f.

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.

d. Inertial Performance.

(1) Inertial system performance must satisfy the criteria of 14 CFR part 121 appendix G.

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.

e. Additional FMS Capabilities.

(1) Automatic position updating 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.

(2) Must be able to accept a position update immediately prior to takeoff.

(3) Must exclude VORs greater than 40 NM from the aircraft.

f. Minimum Performance Standard for each Route or Procedure. The total system error must be less than or equal to 1.0 NM (95 percent) 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 percent).

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.

APPENDIX 3. NAVIGATION DISPLAYS AND FUNCTIONS

1. Navigation data, including a to/from indication and a failure indicator, must be displayed on a lateral deviation display such as CDI, (E)HSI and/or a navigation map display. These shall be used as primary flight instruments for the navigation of the aircraft, for maneuver anticipation and for failure/status/integrity indication. They shall meet the following requirements:

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 five attributes:

(1) The displays shall 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) The lateral deviation scaling should agree with any alerting and annunciation limits, if implemented.

(3) 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 total system accuracy.

(4) The 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 or terminal values.

(5) The lateral deviation display must be automatically slaved to the RNAV computed path. The course selector to the deviation display should be automatically slewed to the RNAV computed path or the pilot must adjust the OBS or HSI selected course to the computed desired track.

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

b. If using a navigation map display, it should give equivalent functionality to a lateral deviation display as described above, (appendix 3, paragraph 1.a. (1-5)), readily visible to the pilot, with appropriate map scales (scaling may be set manually by the pilot).

2. The following system functions are required as a minimum within RNAV equipment:

a. The 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.

b. For operations where the required flightcrew is two pilots, means for both pilots to verify the desired path and the aircraft position relative to the path.

c. 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 total system error. The database must be protected against pilot modification of the stored data.

d. The means to display the validity period of the navigation data to the pilot.

3. The 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 route/procedure to be flown.

4. The entire RNAV segment of the DP or STAR to be flown must be extracted from the navigation database. In this document, the RNAV segment begins at the first occurrence of a named waypoint, track, or course and ends at the last occurrence of a named waypoint, track, or course. Heading legs, prior to the first named waypoint or after the last named waypoint of a procedure, are not part of the RNAV segment and do not have to be loaded from the database. Similarly, direct-to-fix legs prior to the first named waypoint of a procedure are not part of the RNAV segment. While not required, the ability to extract the entire RNAV procedure, including heading and direct-to-fix legs, from the database is a recommended function.

5. The means to display the following items, either in the pilot's primary field of view, or on a readily accessible page on a multipurpose control and display unit (MCDU).

a. The active navigation sensor type.

b. The identification of the active (To) waypoint.

c. The ground speed or time to the active (To) waypoint.

d. The distance and bearing to the active (To) waypoint.

6. Where the MCDU is used to support accuracy checks by the pilot, the capability of displaying lateral deviation with a resolution of at least 0.1 NM.

7. The capability for the navigation system to execute a "Direct to" function.

8. The capability for automatic leg sequencing with display of sequencing to the pilot.

9. The capability to execute procedures extracted from the onboard database including the capability to execute fly-over and fly-by turns.

10. The capability to execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators:

a. The aircraft must have the capability to automatically execute leg transitions and maintain tracks consistent with the following ARINC 424 path terminators, or their equivalent:

- Initial Fix (IF)
- Course to a Fix (CF)

- Direct to Fix (DF)
- Track to Fix (TF)

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: Numeric values for courses and tracks must be automatically loaded from the RNAV system database. However, automatic CF capability is not required for approval to fly: (1) all RNAV routes covered by this AC as these are constructed using TF path terminators, or (2) those ODPs using a DF or TF path terminator for the first segment.

b. The aircraft must have the capability to automatically execute leg transitions consistent with VA, VM and VI ARINC 424 path terminators, or must be able to be manually flown on a heading to intercept a course or to go direct to another fix after reaching a procedure-specified altitude.

c. The aircraft must have the capability to automatically execute leg transitions consistent with CA and FM ARINC 424 path terminators or the RNAV system must permit the pilot to readily designate a waypoint and select a desired course to or from a designated waypoint.

11. The capability to load a named RNAV route into an RNAV system from the database is a recommended function. However, if all or part of the RNAV route (not DP or STAR) is entered through the manual entry of fixes from the navigation database, a TF leg type must be used to define the path between a manually entered by name fix and the preceding and following fixes.

12. The capability to display an indication of the RNAV system failure, including the associated sensors, in the pilot's primary field of view.

13. 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.

14. Database Integrity. The navigation database should be obtained from a database supplier holding an FAA Letter of Acceptance (LOA) in accordance with AC 20-153. This LOA provides recognition of a data supplier's compliance with the data quality, integrity and quality management practices of RTCA DO-200A, Standards for Processing Aeronautical Data. The operator's supplier (e.g., FMS manufacturer) must have a Type 2 LOA. Discrepancies that invalidate a procedure must be reported to the database supplier and affected procedures must be prohibited by an operator's notice to its flightcrew. Aircraft operators should consider the need to conduct ongoing checks of the operational navigation databases in order to meet existing quality system requirements.

NOTE: AC 20-153 contains procedures for database LOAs.

15. It is recommended RNAV systems provide lateral guidance so aircraft remain within the lateral boundaries of the fly-by transition area as defined in DO-236B, section 3.2.5.4.1.