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ADVISORY CIRCULAR

APPROVAL OF AREA NAVIGATION SYSTEMS FOR USE IN THE U. S. NATIONAL AIRSPACE SYSTEM

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

CHANGE

AC NO: 90-45 CHG 1

DATE: 10/20/70

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: APPROVAL OF AREA NAVIGATION SYSTEMS FOR USE IN THE U. S. NATIONAL AIRSPACE SYSTEM

1. PURPOSE. This change deletes certain items found to be in excess of minimum requirements and clarifies certain other items.

2. CHANGES.

   a. Paragraph 2 has been changed to request Air Carriers to advise their Air Carrier District Office of any application made to other offices.

   b. Paragraph 3 has been changed to state that a single system is sufficient for all normal operations.

   c. Appendix A, paragraph 2d, has been changed to eliminate the inference that a flight manual revision or supplement is to be required and to permit provision of operating limitations by means of placards.

   d. Appendix B, paragraph 1b, has been changed to make clear that equipment data need be submitted to FAA only one time, not with each STC application, and to eliminate the need for fault analysis of area navigation equipment. Fault analysis of the installation is retained.

   e. Appendix B, paragraph 2b, is revised to be compatible with the above changes.

   f. Appendix D, paragraph 2.d.(5)(i), has been changed to increase the MDAs by 200' and visibilities by 1/2 mile but not to exceed 2 miles, until operational experience has been gained in the use of the RNAV systems.

   g. Appendix G, paragraph 2, has been deleted.

Initiated by: FS-130 & FS-424

PAGE CONTROL CHART

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1	8/18/69	1	10/20/70

C W Walker
Actg. Associate Administrator for Operations

AC NO: 90-45

DATE: 8/18/69

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: APPROVAL OF AREA NAVIGATION SYSTEMS FOR USE IN THE U. S. NATIONAL AIRSPACE SYSTEM

1. PURPOSE. This advisory circular provides guidelines for implementation of area navigation (RNAV) within the National Airspace System (NAS).

2. CANCELLATION. This advisory circular cancels Advisory Circular 90-27, Operation of Pictorial Display/Course Line Computer Equipment in the National Airspace System, dated 20 August 1965.

3. REFERENCES. U. S. Standard for Terminal Instrument Procedures (TERPs); Advisory Circular 90-28, Course Changes While Operating Under Instrument Flight Rules Below 18,000 Feet Mean Sea Level; Advisory Circular 95-1, Airway and Route Obstruction Clearance; Federal Aviation Regulations Parts 21, 23, 25, 27, 29, 43, 71, 75, 91, 95, 121, and 135, as applicable.

4. HOW TO OBTAIN THIS PUBLICATION.

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      FAA Advisory Circular, AC 90-45
      Approval of Area Navigation Systems for Use in the U. S. National Airspace System
      Dated August 18, 1969

Deputy Associate Administrator for Operations

Initiated by: FS-5

TABLE OF CONTENTS

1. BACKGROUND AND DEFINITIONS.

a. Present navigational methods, based on the use of VOR/DME/TACAN ground facilities, result in routes or airways which lead either directly toward or away from the station. This results in limitations on the configuration and the number of routes available between two points.

b. These limitations take on even more importance considering that arrival and departure procedures are based, in large measure, on the same ground stations which serve the en route structure. This means the funneling effect is compounded by altitude changes for traffic transitioning to or from the en route structure.

c. A logical step toward providing for more efficient utilization of the airspace and airports is the employment of airborne navigation systems that will permit flight over predetermined tracks within prescribed accuracy tolerances without the need to overfly ground-based VOR/DME (VORTAC) navigation facilities. This capability, commonly termed "area navigation," has three principal applications: between any given departure and arrival points along a route structure so organized as to permit reduction in flight distances or reduction in traffic congestion; in terminal areas to permit aircraft to be flown on preorganized arrival and departure flight paths to assist in expediting traffic flow and reduce pilot and controller workload; and to permit instrument approaches within certain limitations to airports/runways not equipped with local landing aids.

d. Although this circular deals largely with navigation in the horizontal plane, it is recognized that a third dimension of control may be provided by the addition of vertical guidance capability.

e. Area navigation expands the usable airspace by allowing the use of routes not solely limited by air navigation facility location. These additional routes provide operational advantages for pilots and controllers by increasing route capability and flexibility.

f. Definitions of particular significance.

(1) Area Navigation (RNAV) - A method of navigation that permits aircraft operations on any desired course within the coverage of station-referenced navigation signals or within the limits of self-contained system capability.

(2) Area Navigation (RNAV) Equipment - Airborne equipment that provides the requirements for area navigation criteria contained in Appendix D.

(3) RNAV Instrument Approach Procedures - Instrument approach procedures based on RNAV and identified by the prefix RNAV followed by the procedure number; i.e., RNAV Rwy 21 or RNAV - A.

(4) RNAV transitions for Initial Approach - Transitions, based on RNAV, from the en route environment to the initial approach fix of an instrument approach procedure. RNAV transitions may be included in conventional approach procedures such as ILS, as well as in complete RNAV approach procedures.

(5) Designated RNAV Route - an area navigation route, based on the current high altitude or low altitude VOR/DME coverage, as designated by the Administrator and published in FARs 71 and 75.

(6) Established RNAV Route - a predefined en route segment, arrival or departure route (including RNAV SIDs and STARs).

(7) Reference Facility - the ground facility used for the identification and establishment of an area navigation route or flight procedure.

(8) Slant Range - the actual distance between aircraft in flight and certain air navigational aids (radar, DME), this distance being greater than the geographical range because of the altitude of the aircraft.

(9) Slant-Range Error - slant-range error is the difference between the distance of an aircraft to a point on the surface and the distance from that point along the surface to a point directly beneath the aircraft.

(10) Tangent Point - the point from which a line perpendicular to the RNAV route centerline passes through a specified VORTAC.

(11) Way Point - A pre-determined geographical position used for route-definition and/or progress-reporting purposes that is defined relative to a VORTAC station position. Two subsequently related way points define a route segment.

(12) Instrument Approach Way Points - Fixes used in defining RNAV instrument approach procedures including the INITIAL APPROACH WAY POINT (IAWP), INTERMEDIATE WAY POINT (INWP), the FINAL APPROACH WAY POINT (FAWP), and the MISSED APPROACH WAY POINT (MAWP).

g. Application of area navigation equipment and procedures in the National Airspace System requires that they be compatible with the VOR/DME system on which route structure and air traffic control are based. Implementation, therefore, requires that area navigation devices employed assure proper positioning with respect to the VOR/DME route structure by reference to the geographic locations of VOR/DME ground facilities. Such systems must further permit navigation along, and within the protected airspace of, conventional VOR routes, airways, and terminal procedures.

h. To assure compatibility with existing ATC routes and procedures, area navigation systems typically compute distances, bearings, and/or command guidance signals relative to "way points" that are used to define RNAV route segments in relation to VOR/DME station locations. A succession of these way points defines the centerline of the route to be flown.

i. The advantages of area navigation are applicable to VFR as well as IFR operations. For VFR operations, straight-line point-to-point navigation, bypassing of congested and restricted areas, and elimination of air navigational facility overhead requirements are the principal advantages gained, and each contributes both to the reduction of pilot workload and to flight safety. Installation requirements for VFR use only are shown in Appendix A, Page 8, Paragraph 4.

j. For IFR operations, area navigation offers similar benefits, but must be conducted in accordance with standards and procedures designed to insure the safe, expeditious, and orderly movement and control of air traffic within prescribed airspace dimensions.

k. Introduction of an area navigation capability into the National Airspace System provides a means of overcoming many of the disadvantages of the present VOR structure. By eliminating the requirement to fly along radials that lead directly to or from the ground station, it is possible to design routes and procedures that better facilitate the movement of traffic. Typical of the benefits that will result are:

(1) Congested area bypass routes.

(2) Multiple routes to allow segregation of traffic according to speed or other operating characteristics.

(3) Pilot navigation of commonly flown radar vector paths.

(4) Improved alignment of routes.

(5) Dual routes for one-way traffic.

(6) Increased instrument approach capability.

(7) Optimum location of holding patterns.

(8) Procedures designed for STOL and helicopter operations.

l. The FAA intends to encourage the installation of area navigation equipment by establishing routes and terminal procedures that are specifically designed for, and are beneficial to, properly equipped users.

m. Immediate attention will be directed to the development of transcontinental and major hub connecting routes along with terminal procedures to serve these routes. Development of other routes and terminal procedures will be consistent with user needs whenever possible.

2. WHERE TO APPLY FOR APPROVAL.

a. Application for approval of an area navigation equipment installation other than those relating to an application for a Supplemental Type Certificate (STC), may be made to any FAA Air Carrier or General Aviation District Office.

b. Application for a Supplemental Type Certificate covering an area navigation equipment installation may be made to any FAA Regional Engineering and Manufacturing Office.

c. Application for approval of new area navigation routes and instrument approach procedures should be made to the appropriate FAA area or regional office.

* d. Air Carriers should advise the responsible Air Carrier District Office of any application made to other offices. *

3. AREA NAVIGATION EQUIPMENT. Equipment that meets the performance specifications outlined in Appendix A is suitable for use within the NAS. A single system will be considered suitable to meet these requirements. Equipment may include doppler radar, inertial, pictorial display/course line computers, or any other technique/device that will ensure compatibility with the operational procedures and route widths prescribed. Pictorial displays or course line computers provide one of the typical methods of operating on an area basis. This method is predicated on utilizing the signals from VOR/DME ground stations, or other facilities offering equivalent accuracy.

APPENDIX A. AIRBORNE AREA NAVIGATION SYSTEMS: ACCEPTABLE MEANS OF COMPLIANCE WITH AIRWORTHINESS REGULATIONS

1. INTRODUCTORY REMARKS.

a. Area navigation systems based on VORTAC stations have four sources of error: (1) ground VOR/DME radiated signal; (2) airborne VOR/DME equipment; (3) flight technical (pilotage); and (4) the area navigation equipment itself. It is assumed further that these are independent errors having such distribution that they may be combined root-sum-square (RSS) fashion. See Appendix C.

b. The means of compliance presented herein apply to systems that use VOR/DME sensor signals either for direct aircraft position determination or for updating aircraft position derived from other sources such as air data computers and magnetic compasses, inertial navigation systems, and doppler radar navigation systems. However, RNAV systems may employ sensor inputs other than VOR/DME without VOR/DME updating, if equivalent accuracies can be demonstrated by means of compliance suitable to such systems.

c. In the development of area navigation, the agency believes that vertical guidance should be introduced which will give third-dimensional capability to the basic two-dimensional (lateral and longitudinal) area navigation system. The agency will develop an addendum to this circular to include criteria for vertical guidance equipment.

d. The problem of slant-range error takes on particular significance under the area navigation concept because of a direct effect upon the intended route of flight. Airborne systems that are dependent upon ground station signals for course guidance are subject to this error, while self-contained systems are not. Of the former, some systems are designed to compensate for slant-range error and others are not.

To avoid implementation delay, airborne systems affected by slant range error will initially be accommodated through procedural compensation by the airspace planning and air traffic control systems. Route design compensations will take the form of limitations on the proximity of route centerlines to ground stations, increased lateral dimensions for routes that must pass in proximity to ground stations and increased lateral spacing of dual or parallel routes. Air traffic control compensations will be in the form of longitudinal and lateral separation criteria that will be large enough to encompass the extremes of slant-range error possibilities. Development of routes designated for the exclusive use of slant-range-corrected users should not be expected as this would amount to reservation of airspace to the detriment of other users and to the flow of traffic in general. However, limited applications for this type of route may exist in areas of otherwise unusable airspace.

Elimination of slant-range error and its attendant compensating procedures is prerequisite to the development of optimum routes and separation criteria. Therefore, an NPRM requiring slant-range correction can be expected by 1 January 1971.

The rulemaking action will require that slant range correction be accomplished entirely within the airborne navigation system to completely eliminate slant-range error.

2. ACCEPTABLE MEANS OF COMPLIANCE (FOR USE UNDER INSTRUMENT FLIGHT RULES).

An acceptable means of compliance with Sections -.1301, -.1309, -.1431, and -.1581, of Part 23, 25, 27, or 29 (as applicable), with respect to area navigation systems, provided for use under IFR conditions, is to satisfy the criteria set forth in this paragraph.

a. Accuracy.

(1) Systems using VOR/DME for continuous navigation information. The total of the error contributions of the airborne equipment (VOR/DME and area navigation) and the following specific error contributions, when combined RSS, should not exceed the values shown in Tables 1, 2, and 3, Appendix A, pages 9, 10 and 11:

VOR ground station	± 1.9°	95% confidence
DME ground station	± 0.1 NM	
Pilotage (en route)	± 2.0 NM	
Pilotage (terminal)	± 1.0 NM	
Pilotage (approach)	± 0.5 NM	

(2) Systems referenced to VOR/DME, but not using continuous VOR/DME information, should be capable of accuracies equivalent to that contained in 2.a.(1) above, over a period of time equal to the update cycle.

(3) All equipment approved for use under instrument flight rules should be at least capable of meeting the accuracy criteria of 2.a.(1) above, specified for en route and terminal usage (Tables 1 and 2). Equipment which does not meet the accuracy criteria of 2.a.(1) above, for the approach case (Table 3) should be placarded "RNAV Instrument Approaches Not Authorized."

NOTE: Rule making will be considered by 1 January 1971 to specify types of airborne equipment required and the accuracy required of that equipment for use in the air traffic control system. Equipment and accuracy requirements will vary according to type of operation. The following categories of operations are foreseen:

1. IFR operations, including approaches, in designated high-density terminals.

2. IFR operations along en route segments and within terminal areas, including approaches (other than designated high-density terminals) where air traffic control service is provided.

3. VFR operations in designated high-density terminals/routes.

4. VFR operations in terminal areas (other than designated high-density terminals) where air traffic control service is provided.

(4) While specific airborne equipment error contributions which are considered typical of the actual environment have been assumed in Tables 1, 2, and 3, further improvements through reduction of individual error elements are considered possible. Absolute limitations are not implied, and systems based on different combinations of errors may be accepted provided equivalent overall accuracy is attained. (See Appendix C).

b. Area Navigation System Design.

(1) General. The systems will normally use VOR/DME input sensor signals (or use combinations of VOR and DME for updating purposes) and indicate aircraft positions relative to the RNAV route and selected way point. It should give no operationally significant misleading indication.

Systems may be designed to utilize other sensor inputs if equivalent accuracy can be demonstrated.

(2) Checking of Input. If the system requires pilot input functions (such as the designations of way points), provisions should be made to enable the pilot to check the correctness of the inputs.

(3) Failure Warning. Provision should be made to alert the crew upon occurrence of any reasonably probable failure of major system functions or loss of inputs, including those that would affect aircraft position, heading, command course, or command heading indications.

(4) Performance Check. Provision should be made for checking the system's performance on the ground and in flight. This may be a built-in check, an auxiliary test system, or a procedural check.

(5) Response Time. The navigation display should indicate aircraft position, to the accuracy specified in Paragraph 2.a, assuming that navigation sensor outputs are available.

(a) During flight in any direction at the maximum ground speed declared by the equipment manufacturer; and,

(b) Within five seconds after any normal maneuver, assuming sensor inputs are not lost during the maneuver.

(c) The time lag between selection of data and guidance derived from the display of the data should not be operationally significant.

NOTE: Terminal area speed limitations are taken into account in connection with this provision. Moving elements of the navigation display may be damped.

(6) Environmental Conditions. The area navigation equipment should be capable of satisfying the criteria set forth in Paragraph 2.a and 2.b(5) over the environmental ranges expected to be encountered in actual aeronautical operations. In demonstrating compliance, the environmental conditions outlined in Radio Technical Commission for Aeronautics Document DO-138, titled "Environmental Conditions and Test Procedures for Airborne Electronic/Electrical Equipment and Instruments" dated June 27, 1968, or other appropriate environmental standards may be used.

c. Area Navigation Equipment Installation.

(1) Location of the primary RNAV display. Where area navigation equipment with one or more display elements is to be installed, and a display element is to be used as a primary flight instrument in the guidance and control of the aircraft, it should be located where it is clearly visible to the pilot with the least practicable deviation from his normal position and from his line of vision when he is looking forward along the flight path.

(2) Failure protection. Any reasonably probable failure of the airborne navigation equipment should not affect the normal operation of required equipment connected to it, nor cause a flight hazard.

(3) Radio frequency interference. The area navigation equipment should not be the source of objectionable radio frequency interference, nor be adversely affected by radio frequency emissions from other equipment in the aircraft.

(4) Manufacturer's instructions. The area navigation equipment should be installed in accordance with instructions and limitations provided by the manufacturer.

d. Aircraft Flight Manual. If an aircraft flight manual is provided by the aircraft manufacturer, its FAA-approved portion may contain the following information on the area navigation equipment:

(1) Normal procedure for operating the equipment;

(2) Equipment-operating limitations; and,

(3) Emergency operating procedures (if applicable).

* If not contained in the aircraft flight manual, information on equipment operating limitations should be provided to the pilot by means of placards. The aircraft flight manual or placard should state "RNAV Instrument Approaches Not Authorized" if the equipment does not meet the accuracy requirements for approach, reference Appendix A, paragraph 2a(1) and (3), and Table 3. Revisions or supplements to the flight manual must be approved by the Regional Chief of the Engineering * and Manufacturing Branch.

3. TESTING PROCEDURE (FOR EQUIPMENT PROVIDED FOR USE UNDER INSTRUMENT FLIGHT RULES).

a. General. An applicant for approval of an area navigation system installation in an aircraft may show that he has satisfied the criteria in Paragraph 2 by a combination of bench tests of the individual components (including VOR and DME) and ground/flight tests of the entire installed area navigation system. The bench tests may have already been performed by the individual component manufacturer (during design and construction) or by the installer (on behalf of a previous customer). Such bench test data, if certified by the manufacturer or installer, are acceptable. In addition, the applicant may refer to applicable TSO standards, if the manufacturer of the equipment certifies that his equipment meets those standards.

b. Bench Tests.

The following tests may be performed on the bench or with the navigation system installed in the aircraft:

(1) Test equipment. Bench test equipment should be capable of simulating the input signals from VOR/DME and/or other sensors and of varying those signals over the ranges stipulated in Paragraph 3.b.(2).

(2) Accuracy testing.

(a) Variables to be considered. Each variable that has a significant effect on position error should be investigated over its range, and the error analysis should show the effects of reasonably probable variations of these variables on total system accuracy. The statistical technique described in RTCA Paper 48-62/DO-114, dated April 18, 1962, may be used as a guide.

(b) Static test. Position accuracy should be measured statically as the error in displayed position relative to the theoretical position obtained from perfect signal inputs (range and bearing from a known station location). Simulated range and bearing signals are introduced into the area navigation equipment. Combinations of ranges from zero up to the maximum distance for which the equipment is designed, and bearings from zero to 360 degrees, should be inserted as input signals. For each set of input signals, the corresponding display output should be recorded. The total system error is then computed for each test point by adding RSS the appropriate specific error contributions listed in 2.a.(1) above. The values shown in Tables 1, 2 and 3, Appendix A, should not be exceeded.

(c) Dynamic test. In addition to the static test, a dynamic accuracy test should be performed utilizing simulated VOR/DME inputs varied in range and bearing in order to assess the ability of the system to smooth variable input signals without incurring excessive lag. These tests should be performed with representative simulated airspeeds throughout the range for which the equipment is designed. During any such tests the measured airborne VOR/DME and RNAV equipment error components should not be inconsistent with the total system accuracies specified in Paragraph 2.a.

(d) Systems having map-type displays. If the system uses a map-type pictorial display of aircraft position as a primary means of steering guidance, the accuracy determination should take into account any error contribution by the cartography.

c. Ground/flight tests.

(1) Ground tests. After the area navigation system has been installed, but before the aircraft is flown, an operational/functional check should be performed to ensure that the system has been installed in accordance with the installation criteria in Paragraph 2.c. (and with all applicable airworthiness regulations) and that it functions properly and safely.

(2) Determination of when flight tests are necessary. Flight tests for accuracy in the en route and terminal cases are necessary only if the system accuracy is not adequately determined by signal simulation as described in 3.b. above, or if it appears that the resolution of the pilot display is such that the assumed pilotage error of ± 1.0 NM may be exceeded.

At least one flight test for accuracy in the approach case is necessary, as the pilot display used for this application may have an appreciable effect on the accuracy obtained in flight. Additional flight tests for accuracy in the approach case are necessary only if the system accuracy is not adequately determined by signal simulation as described in 3.b. above.

(3) <u>Accuracy tests in flight</u>. When flight tests are necessary, in addition to ground tests, to demonstrate satisfactory performance of the area navigation equipment, the airplane should be flown solely by reference to the RNAV display and other standard flight instruments, at a relatively low altitude under VFR conditions, with a safety pilot, and if practicable under ground radar surveillance as follows:

(a) Along the length of an approved area navigation route segment;

(b) In accordance with an approved area coverage terminal area procedure; and

(c) In accordance with an approved area coverage approach procedure.

In each case, the area navigation system is satisfactory if the equipment meets the accuracy requirements of Paragraph 2.a. as determined by direct visual reference to identifiable ground check points and a large scale map of the area on which are shown route segment centerlines and boundary widths applicable to the distance from the reference facility.

(4) <u>Functional tests in flight</u>. The area navigation system should be checked out in flight to determine whether the design and installation criteria in Paragraph 2.b. and 2.c. are satisfied.

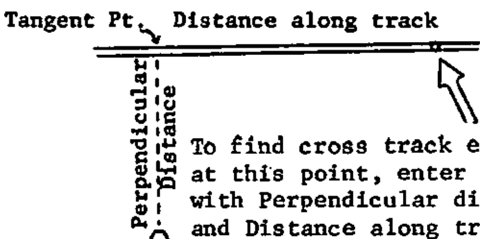
4. <u>ACCEPTABLE MEANS OF COMPLIANCE (FOR EQUIPMENT PROVIDED FOR USE UNDER VISUAL FLIGHT RULES ONLY)</u>.

a. An acceptable means of compliance with Sections -.1301, -.1309, -.1431 and -.1581, of Part 23, 25, 27, or 29 (as applicable), with respect to area navigation systems provided for use under VFR conditions only, is to satisfy the criteria in Paragraph 2.c. and 3.c(1) above, and to placard the aircraft to limit the use of the area navigation system to VFR only.

b. Airborne area navigation equipment installed under Paragraph 4.a. may be approved by means of a Form 337 or Supplemental Type Certificate.

AREA NAVIGATION TRACK ERROR (95 PCT PROBABILITY)

PERP. DIST.	DISTANCE ALONG TRACK FROM TANGENT POINT 0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	200	250	300
0.	2.1	2.2	2.4	2.8	3.2	3.7	4.3	4.8	5.4	5.9	6.5	7.1	7.7	8.3	8.9	9.5	12.6	15.6	18.7
5.	2.1	2.2	2.4	2.8	3.2	3.7	4.3	4.8	5.4	5.9	6.5	7.1	7.7	8.3	8.9	9.5	12.6	15.6	18.7
10.	2.1	2.2	2.4	2.8	3.2	3.7	4.3	4.8	5.4	5.9	6.5	7.1	7.7	8.3	8.9	9.5	12.6	15.6	18.7
15.	2.1	2.2	2.4	2.8	3.2	3.7	4.3	4.8	5.4	6.0	6.5	7.1	7.7	8.3	8.9	9.5	12.6	15.6	18.7
20.	2.1	2.2	2.5	2.8	3.3	3.8	4.3	4.8	5.4	6.0	6.5	7.1	7.7	8.3	8.9	9.5	12.6	15.6	18.7
25.	2.2	2.3	2.5	2.9	3.3	3.8	4.3	4.8	5.4	6.0	6.6	7.1	7.7	8.3	8.9	9.5	12.6	15.6	18.7
30.	2.3	2.3	2.6	2.9	3.3	3.8	4.3	4.9	5.4	6.0	6.6	7.2	7.7	8.3	8.9	9.5	12.6	15.6	18.7
35.	2.3	2.4	2.6	3.0	3.4	3.8	4.4	4.9	5.4	6.0	6.6	7.2	7.8	8.4	9.0	9.6	12.6	15.6	18.7
40.	2.4	2.5	2.7	3.0	3.4	3.9	4.4	4.9	5.5	6.0	6.6	7.2	7.8	8.4	9.0	9.6	12.6	15.6	18.7
45.	2.5	2.5	2.7	3.1	3.5	3.9	4.4	5.0	5.5	6.1	6.6	7.2	7.8	8.4	9.0	9.6	12.6	15.7	18.7
50.	2.6	2.6	2.8	3.1	3.5	4.0	4.5	5.0	5.5	6.1	6.7	7.2	7.8	8.4	9.0	9.6	12.6	15.7	18.7
55.	2.6	2.7	2.9	3.2	3.6	4.0	4.5	5.0	5.6	6.1	6.7	7.3	7.9	8.4	9.0	9.6	12.6	15.7	18.7
60.	2.7	2.8	3.0	3.3	3.7	4.1	4.6	5.1	5.6	6.2	6.7	7.3	7.9	8.5	9.1	9.7	12.7	15.7	18.8
65.	2.8	2.9	3.1	3.4	3.7	4.2	4.6	5.1	5.7	6.2	6.8	7.3	7.9	8.5	9.1	9.7	12.7	15.7	18.8
70.	2.9	3.0	3.2	3.5	3.8	4.2	4.7	5.2	5.7	6.3	6.8	7.4	8.0	8.5	9.1	9.7	12.7	15.7	18.8
75.	3.1	3.1	3.3	3.5	3.9	4.3	4.8	5.3	5.8	6.3	6.9	7.4	8.0	8.6	9.1	9.7	12.7	15.7	18.8
80.	3.2	3.2	3.4	3.6	4.0	4.4	4.8	5.3	5.8	6.4	6.9	7.5	8.0	8.6	9.2	9.8	12.7	15.8	18.8
85.	3.3	3.3	3.5	3.7	4.1	4.5	4.9	5.4	5.9	6.4	7.0	7.5	8.1	8.6	9.2	9.8	12.8	15.8	18.8
90.	3.4	3.4	3.6	3.8	4.2	4.6	5.0	5.5	6.0	6.5	7.0	7.6	8.1	8.7	9.3	9.8	12.8	15.8	18.8
95.	3.5	3.6	3.7	3.9	4.3	4.6	5.1	5.5	6.0	6.5	7.1	7.6	8.2	8.7	9.3	9.9	12.8	15.8	18.9
100.	3.6	3.7	3.8	4.1	4.4	4.7	5.2	5.6	6.1	6.6	7.1	7.7	8.2	8.8	9.3	9.9	12.9	15.8	18.9
105.	3.8	3.8	3.9	4.2	4.5	4.8	5.2	5.7	6.2	6.7	7.2	7.7	8.3	8.8	9.4	10.0	12.9	15.9	18.9
110.	3.9	3.9	4.1	4.3	4.6	4.9	5.3	5.8	6.2	6.7	7.3	7.8	8.3	8.9	9.4	10.0	12.9	15.9	18.9
115.	4.0	4.1	4.2	4.4	4.7	5.0	5.4	5.9	6.3	6.8	7.3	7.8	8.4	8.9	9.5	10.1	13.0	15.9	18.9
120.	4.1	4.2	4.3	4.5	4.8	5.1	5.5	5.9	6.4	6.9	7.4	7.9	8.4	9.0	9.5	10.1	13.0	16.0	19.0
125.	4.3	4.3	4.4	4.6	4.9	5.2	5.6	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.6	10.2	13.0	16.0	19.0
130.	4.4	4.4	4.6	4.8	5.0	5.3	5.7	6.1	6.6	7.0	7.5	8.0	8.6	9.1	9.7	10.2	13.1	16.0	19.0
135.	4.5	4.6	4.7	4.9	5.1	5.4	5.8	6.2	6.7	7.1	7.6	8.1	8.6	9.2	9.7	10.3	13.1	16.1	19.0
140.	4.7	4.7	4.8	5.0	5.2	5.6	5.9	6.3	6.7	7.2	7.7	8.2	8.7	9.2	9.8	10.3	13.2	16.1	19.1
145.	4.8	4.8	4.9	5.1	5.4	5.7	6.0	6.4	6.8	7.3	7.8	8.3	8.8	9.3	9.8	10.4	13.2	16.1	19.1
150.	5.0	5.0	5.1	5.3	5.5	5.8	6.1	6.5	6.9	7.4	7.8	8.3	8.8	9.4	9.9	10.4	13.2	16.2	19.1



To find cross track error at this point, enter table with Perpendicular distance and Distance along track from tangent point.
The along track error is found by interchanging the above perpendicular and along track distance values.

EXAMPLE:
Perp. dist. 70 NM
Along track 100 NM
Cross track error = ± 6.8 NM

100 NM on perp. scale
70 NM on along track scale
Along track error = ± 5.6 NM

EXAMPLE:
Perp. dist. 0 NM
Along track 51 NM
Cross track error = ± 4.0 NM (3.8)

51 NM on perp. scale
0 NM on along track scale
Along track error = ± 2.6 NM

Ground
VOR 1.9°
DME 0.1 NM
Airborne
VOR 3.0°
DME 3% or 0.5 NM

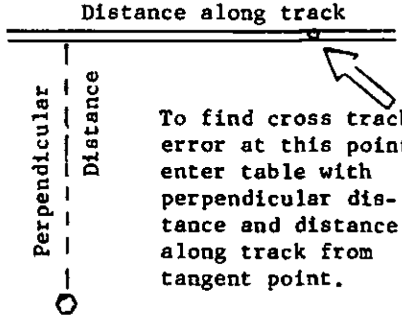
Computer 0.5 NM
Pilot 2.0 NM

Table 1

AREA NAVIGATION TRACK ERROR (95 PERCENT PROBABILITY)

PREP. DIST.	DISTANCE ALONG TRACK FROM TANGENT POINT 0	2	4	6	8	10	12	14	16	18	20	22	24	26
0.		1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
2.	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
4.	1.2	1.2	1.2	1.2	1.2	1.3	1.4	1.4	1.5	1.6	1.7	1.8	1.9	2.0
6.	1.2	1.2	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.7	1.8	1.9	2.0
8.	1.2	1.2	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.7	1.8	1.9	2.0
10.	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.6	1.7	1.8	1.9	2.0
12.	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.9	2.0
14.	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.9	2.0
16.	1.2	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.0
18.	1.2	1.3	1.3	1.3	1.3	1.4	1.4	1.5	1.6	1.7	1.7	1.8	1.9	2.0
20.	1.3	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.7	1.8	1.9	1.9	2.0
22.	1.3	1.3	1.3	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.0	2.1
24.	1.3	1.3	1.4	1.4	1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.9	2.0	2.1
26.	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.6	1.7	1.8	1.8	1.9	2.0	2.1

Tangent Pt.



To find cross track error at this point, enter table with perpendicular distance and distance along track from tangent point.

The along track error is found by interchanging the above perpendicular and along track distance values.

EXAMPLE:
Perp. dist. 18 NM
Along track 14 NM
Cross track error
= ± 1.5 NM

14 NM on perp. scale
18 NM on along track scale
Along track error = ± 1.6 NM

EXAMPLE:
Perp. dist. 0 NM
Along track 25 NM
Cross track error
= ± 2.0 NM

25 NM on perp. scale
0 NM on along track scale
Along track error = ±1.3NM

GROUND
VOR 1.9
DME 0.1 NM
AIRBORNE
VOR 3.0°
DME 3% or
0.5 NM
COMPUTER 0.5 NM
PILOT 1.0 NM

TERMINAL APPROACH TABLE NO. 2

AREA NAVIGATION TRACK ERROR (95 PCT PROBABILITY)

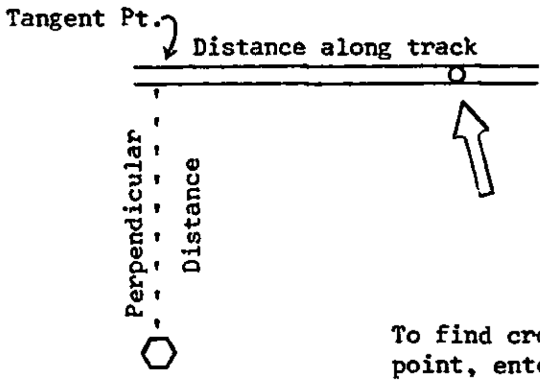
PERP. DIST.	DISTANCE ALONG TRACK FROM TANGENT POINT					
	0	2	4	6	8	10
0.			0.7	0.8	0.9	0.9
2.			0.8	0.8	0.9	0.9
4.			0.8	0.9	0.9	1.0
6.	0.9	0.9	0.9	0.9	0.9	1.0
8.	0.9	0.9	0.9	0.9	0.9	1.0
10.	0.9	0.9	0.9	0.9	1.0	1.0

EXAMPLE:
Perp. dist. 6 NM
Along track 8 NM
Cross track error = ±0.9NM

8 NM on Perp. scale
6 NM on along track scale
Along track error = ±0.9 NM

EXAMPLE:
Perp. dist. 0 NM
Along track 10 NM
Cross track error = ±0.9 NM
rounded from 0.87 NM

10 NM on Perp. dist. scale
0 NM on along track scale
Along track error = ±0.9 NM
rounded from 0.85 NM



To find cross track error at this point, enter table with Perpendicular distance and Distance along track from tangent point.

The along track error is found by interchanging the above perpendicular and along track distance values.

GROUND		
	VOR	1.9°
	DME	0.1NM
AIRBORNE		
	VOR	3.0°
	DME	3% or 0.5 NM
COMPUTER		0.5 NM
Pilot		0.5 NM

FINAL APPROACH TABLE NO. 3

APPENDIX B. PROCEDURE FOR OBTAINING FAA DATA APPROVAL BY SUPPLEMENTAL TYPE CERTIFICATE (STC) OR MAJOR REPAIR AND ALTERATION (FORM 337) (FOR EQUIPMENT PROVIDED FOR USE UNDER INSTRUMENT FLIGHT RULES)

1. APPROVAL OF TECHNICAL DATA BY SUPPLEMENTAL TYPE CERTIFICATE (STC).

a. What the STC applicant does:

(1) Makes an application for STC at the FAA Regional Engineering and Manufacturing office. Early contact is wise, since scheduling may be critical. FAA evaluates the data submitted by the applicant (see Paragraph 1.b.), issues a Type Inspection Authorization (TIA), and participates in ground/flight tests outlined in Appendix A, Paragraph 3.c. An STC is issued when all airworthiness requirements are met. If the submitted data is adequate, the STC authorizes similar installations in the same aircraft type.

(2) Designs and constructs his area navigation system installation to the criteria set forth in Appendix A, Paragraph 2.

* (3) Obtains, from the equipment manufacturer or the installer, the bench test data described in Appendix A, Paragraph 3.b., or an appropriate certification of accuracy per Paragraph 3.a., or conducts these bench tests himself. *

(4) Makes available an aircraft (with the area navigation system installed) for ground inspection and flight test. The applicant is responsible for furnishing a qualified flight crew for conducting the required flight tests.

b. Data submitted by the STC applicant. The following kinds of data may be submitted for FAA airworthiness evaluation:

(1) Equipment data, such as:

(a) Equipment schematics.

(b) Equipment manufacturer's operating instructions and installation instructions.

(c) Equipment manufacturer's quality control procedures

* NOTE: Equipment data is submitted for original installation only. *

(2) Fault analysis covering installation.

(3) Installation information and/or photographs.

(4) Any needed structural substantiation.

(5) Electrical schematics.

(6) Any needed flight manual revision or supplement, or placard drawings.

c. What the Equipment Manufacturer Can Do.

(1) Assist the STC applicant by supplying the data specified in Paragraphs 1.a(3) and 1.b(1).

(2) Perform the bench tests described in Appendix A, Paragraph 3.b. and certify (to the applicant or FAA) that the accuracy criteria in Appendix A, Paragraph 2.a, are satisfied.

2. APPROVAL OF TECHNICAL DATA BY FORM 337 (FOR USE UNDER INSTRUMENT FLIGHT RULES).

a. Data Submitted by the Applicant. The following alteration data for the equipment installation will be submitted with a properly executed Form 337:

(1) Data to confirm that the requirements of Appendix A, Paragraph 2, have been met.

(2) Data to confirm that the requirements of Appendix A, Paragraphs 3.b and 3.c have been met.

b. Additional Data Which May Be Required. If required for FAA Airworthiness evaluation by the FAA District Office approving the technical data, the applicant may also be required to furnish a copy of the equipment schematics, manufacturer's operating and
* installation instructions, fault analysis for installation, instal-*
lation details and/or photographs, substantiation of structural changes, electrical schematics, and any appropriate proposed flight manual revision and/or placards.

c. Inspection of Aircraft. Make the aircraft available for data conformity inspection.

APPENDIX C. SOURCES OF NAVIGATION SYSTEM ERROR

1. GENERAL. The establishment of relationships between navigation system accuracy and IFR aircraft separation criteria or route widths is a complex process. The first problem is to determine a reasonably achievable level of navigation system accuracy. This must be based not only on analysis of the measurable system error elements for state-of-the-art equipment but also on a series of intangibles judged primarily on the basis of experience.

   Current separation criteria, based on such analysis and experience, provide aircraft under IFR control a high degree of protection against collision with other aircraft or obstructions. These criteria take into account the measured accuracies of the VOR/DME ground facilities and airborne equipment and judgments as to how pilots actually fly their airplanes. Accumulating evidence shows that VOR/DME information, when used with area navigation computing and display devices and presented properly to the pilot, offers the potential for an even more efficient utilization of the airspace while maintaining current standards of in-flight safety.

2. CURRENT RELATIONSHIP BETWEEN NAVIGATION ACCURACY AND ROUTE WIDTH. The system of airways and routes used in the United States has widths of route protection based on a VOR system use accuracy of ±4.5 degrees on a 95 percent probability basis. The ±4.5 degrees for VOR justifies the application of ±4 nautical mile route width out to a distance of 51 nm from the facility and a widening of route protection on the ±4.5 degree basis beyond 51 miles.

3. SOURCES OF ERROR. The basic assumption is that four sources of error - ground VOR radiated signal, airborne VOR receiver equipment, area navigation equipment, and pilotage - contribute independent errors of such distribution that they may be combined in RSS fashion. This is the normal assumption used traditionally by the FAA and is required by the method recommended by ICAO Annex 10 for the determination of VOR system use accuracy (ICAO Annex 10, Second Edition, April 1968, Attachment C to Part I, Paragraph 3.6, VOR System Accuracy). All errors are based on a 95 percent probability basis.

   Errors from the four major sources listed above are actually composite values including error contributions from various factors. For example, "errors in radiated signals" include propagation errors as well as errors in the transmitted signals arising from geographical siting and magnetic alignment of the ground station.

a. "Airborne VOR equipment errors," in accordance with common practice, include not only errors in the receiver outputs, but also errors contributed by the converter and the conventional course selector and deviation indicator. In those cases in which an area navigation system accepts inputs directly from the receiver, the error components normally included for the converter and indicator are not incurred and, therefore, the appropriate value for "airborne VOR equipment error" can be correspondingly reduced. (NOTE: This factor is considered subsequently as one type of error compensation that may be afforded by area navigation equipment). The errors for DME receivers to be used in conjunction with area navigation equipment, although small compared to the total system use error, are taken into account in Tables 1, 2, and 3, Appendix A.

b. "Area navigation equipment error" includes error components contributed by any input, output, or signal conversion equipment used, by any computing element employed, by the display as it presents either aircraft position or guidance commands (e.g., course deviation or command heading), and by any course definition entry devices employed. For systems in which charts are incorporated as integral parts of the display, the "area navigation equipment error" necessarily includes charting errors to the extent that they actually result in errors in controlling the position of the aircraft relative to a desired path over the ground. To be consistent, in the case of symbolic displays not employing integral charts, any errors in way point definition directly attributable to errors in reference charts used in determining way point positions should be included as a component of "area navigation equipment error." This type of error is virtually impossible to handle and in general practice highly accurate published way point locations are used to the greatest extent possible in setting up such systems to avoid such errors (and to reduce workload).

c. "Pilotage error" includes the so-called "flight technical error" which refers to the accuracy with which the pilot controls the aircraft as measured by his success in causing the indicated aircraft position to match the indicated command or desired position on the display. It also includes any inaccuracies he may introduce in manually defining way points or desired route segments. Pilotage error will vary widely depending on many factors. A few very important ones are: pilot experience, competing pilot workload, fatigue, and motivation. Equipment and ambient environment variables also affect pilotage directly and measurably, such as: processing of the basic display inputs (i.e., smoothing and quickening), whether or not heading is presented integrally with position and/or command guidance indications, display scale factors, numerous display configuration variables, aircraft control dynamics, air turbulence, and many more. Strictly speaking, with autopilot coupling, "flight technical error" becomes "autopilot error." These factors must be taken into account in arriving at empirical values for pilotage contribution to system use accuracy.

The most widely used figure for flight technical error in system use accuracy assessments is $\pm 2.5^{\circ}$. It assumes an angular as opposed to a linear deviation display, and consequently the true value is likely to be range dependent, decreasing in linear terms as the station or way point is approached. Considering only those factors directly under the control of the area navigation equipment designer, mainly the display related design variables mentioned previously, it may be possible to achieve a flight technical error that is a small fraction of the 2.5° value.

Evaluation of area navigation equipment to the present time indicates that the flight technical error, using such equipment, is linear in nature. A value of ± 2.0 nm is typical for the en route case and ± 0.5 nm is typical for final approach operations.

4. COMBINING THE ERROR ELEMENTS. Based on the assumptions that the variable errors from the various sources are normally distributed and independent, they may be combined in RSS (root-sum-squares) fashion. Thus, the standard deviations obtained from the various contributing sources may be combined geometrically rather than arithmetically by taking the square root of the sum of their squares:

$$\sigma_{total} = \sqrt{\sigma_1^2 + \sigma_2^2 \ldots + \sigma_n^2}$$

5. ERROR BUDGETING.

a. In optimizing a navigation system design, it is generally desirable to avoid having the error from one source much larger than those from the other sources since, by the RSS method of combination, it will contribute disproportionately to the total error. However, it may be technically easier, cheaper, or operationally more desirable to reduce the error from one source rather than another in order to meet a total system use accuracy requirement.

b. In establishing an error budget, a system designer may trade off a reduction in the errors from one or more sources against increases in the errors from others. Thus, in adding an area navigation computing and display capability to the basic VOR/DME system, it is necessary and possible to compensate for the errors introduced by the new equipment by means of reductions in errors from other sources.

c. The following hypothetical example illustrates how this may be done.

(1) Assume that a company sells an airborne VOR system designed to fly within a ±4 nm route width to a distance of 51 nm from a ground facility on the basis of the following error budget:

(2)

Ground VOR Station Error	$\pm 1.9^{\circ}$ @51 nm = 1.7 nm cross track error
Airborne VOR Equipment Error	$\pm 3.0^{\circ}$ @51 nm = 2.7 nm cross track error
Ground DME Error	±0.1 nm on radial = 0.0 nm cross track error
Airborne DME Error	±3% or 0.5 nm on radial = 0.0 nm cross track error
Pilotage Error	$\pm 2.5^{\circ}$ @51 nm = 2.2 nm cross track error

(3) The error elements combine to make:

$$\text{Total Error} = \pm\sqrt{1.7^2 + 2.7^2 + 2.2^2}$$
$$= \pm\ 3.88$$

(4) In designing a new system containing area navigation devices contributing an error element of ±2 nm (equivalent to $\pm 2.3^{\circ}$ at 51 nm), the system engineer finds that the total error of the new system would not satisfy the requirement of a ±4 nm route width to 51 nm range if the other error elements remained the same. However, he also finds that he can compensate for the added error component in two ways:

(a) By picking off signals directly from the VOR receiver thereby not incurring the usual converter and indicator errors so that the airborne VOR equipment error is reduced from $\pm 3^{\circ}$ to $\pm 2^{\circ}$. Thus the cross track error becomes ±1.8 nm.

(b) By employing a linear RNAV display which permits an assumed pilotage error of ±2.0 nm which is consistent with current studies regarding pilotage.

(5) The system engineer now recomputes the total system error on the basis of the following error budget:

$$\text{Total Error} = \pm\sqrt{(1.7)^2 + (1.8)^2 + (2.0)^2 + (2.0)^2}$$
$$= \pm\ 3.76 \text{ nm at 51 nm from the facility (95\% probability)}$$

The new system meets the design accuracy requirement with an increased margin of safety. In this example, the DME station and airborne equipment errors did not contribute to cross track error. With track orientation other than along a radial, an increase in DME contribution will be offset by a decrease in VOR effect.

APPENDIX D. EN ROUTE AND TERMINAL AIR TRAFFIC AND FLIGHT PROCEDURES

1. EN ROUTE AND TERMINAL CRITERIA.

a. Factors to be considered for approval will include FAA capability to provide service, anticipated volume of traffic, and compatibility of the routing with existing airways, routes, traffic and procedures.

b. All approved area navigation routings will be checked for adequate signal coverage and frequency protection. Those approved for general public use will be published and depicted on United States Government Flight Information Publication En Route Charts, Standard Instrument Departure Charts, Terminal Charts, or in the Airman's Information Manual, as appropriate.

NOTE: For equipment requiring VOR/DME inputs, all approved RNAV routes require uninterrupted VOR/DME signal reception as opposed to Victor airway MEA's which now may incorporate signal gap areas.

c. The lack of slant-range correction on airborne equipment during initial implementation requires that route dimensions be enlarged to encompass slant range error. The amount of additional protected airspace provided will be determined by proximity to reference facilities and maximum authorized altitudes. This additional airspace provided will be consistent with the amount of slant-range error involved.

d. The airspace to be protected is shown on the Area Navigation Route Width Summary, (Figure 1, page 13), and is described as follows. Route Widths will be:

(1) Four miles along terminal routes where the point of tangency of the route centerline lies within 53 miles of the ground station on which the route is based. The route boundaries expand to 8 miles at the point where the route centerline intercepts the boundary of the 4-mile zone. Terminal routes are associated with procedures used for ingress and egress to or from the en route structure.

(2) Eight miles wide along routes where the point of tangency of the route centerline lies within 102 miles of the ground station. The route boundaries expand at 3.25° at the point where the route centerline intercepts the boundary of the 8-mile zone.

(3) When the point of tangency is beyond the 102-mile limit, the 8-mile route width is increased by 0.5 miles for each 10-mile increment beyond 100 miles from the ground station. At this point the route boundaries expand at 3.25°.

e. Way points on published routes will be identified by latitude/longitude and bearing and distance from the ground facility on which they are based. In addition, geographical names will be assigned to way points, if required for flight planning or ATC purposes.

f. Changeover points for approved area navigation routes will be published with the distance relating to the way points.

g. Obstacle clearance criteria will be those described in Advisory Circular 95-1, Paragraphs 4, 5, and 7, except that the primary obstacle clearance area will be in accordance with the route dimension description in 1.d., above. Secondary areas will have the following widths:

(1) One mile either side of the primary 4-mile route width.

(2) Two miles either side of a primary 8-mile route width.

(3) In addition, the secondary area expands 4.9° where the primary area expands 3.25°.

h. Area navigation en route segments will be identified to distinguish them from the present airways and jet routes. Standard Instrument Departures (SID) and Standard Terminal Arrival Routes (STAR) that are established for the exclusive use of area navigation equipped aircraft will be identified by use of the term "RNAV" immediately preceding the words "Departure" and "Arrival" respectively. For example: Brooks One RNAV Departure; Richards Three RNAV Arrival.

i. Random or impromptu area navigation routes are authorized only when air traffic control radar is used to monitor navigation and aircraft separation. Definition of such routes will, in addition to current route definition methods, be defined in terms of DEGREE/DISTANCE fixes (example -- "DIRECT TO THE TWO FIVE MILE FIX ON THE APPLETON THREE ONE ZERO RADIAL") or offset from published or established routes/airways at a specified distance and direction (example -- "EIGHT MILES OFFSET RIGHT OF VICTOR SIX").

j. En route procedures shall be evaluated using existing flight inspection facility performance data, or by flight inspection of the procedure when facility data is lacking.

2. <u>INSTRUMENT APPROACH PROCEDURE CRITERIA</u>.

a. <u>Scope</u>. This Appendix contains criteria which shall be used to formulate, review, approve, and publish RNAV procedures for instrument approach of aircraft to civil airports. Application for military operations will be incorporated at a later date.

b. Types of Procedures. Criteria are provided for the following types of authorized terminal instrument procedures:

(1) Straight-in. A descent in an approved procedure in which the final approach course alignment permits a straight-in landing.

(2) Circling Approach. A descent in an approved procedure to an airport for a circle-to-land maneuver.

c. Numbering.

(1) Numbering of Procedures. Terminal instrument procedures should be numbered to be meaningful to the pilot, and to permit ready identification in air traffic control phraseology.

(2) Straight-In Approach. When the RNAV procedures meet the straight-in runway approach course alignment criteria, the procedure shall be numbered as follows: RNAV Rwy. 21, etc. (See Paragraph (d)3, page 9).

(3) Circling Approach. When the procedures do not meet straight-in runway approach criteria and are published with circling minimums only, they shall be designated alphabetically in sequence (Example: RNAV-A, RNAV-B, etc.).

d. General Criteria - Common Information.

(1) Units of Measurement. Units of measurement shall be expressed as set forth below:

(a) Courses and Radials. Courses shall be expressed in degrees magnetic. Radials shall also be expressed in degrees magnetic, and shall further be identified as radials by prefixing the letter "R" to the magnetic bearing FROM the facility. For example: R-027 or R-010.

(b) Altitudes. Units of measurement for altitude in this publication are feet. In published procedures, altitudes below the transition level shall be expressed in feet above mean sea level (MSL). Above the transition level altitudes in published procedures shall be expressed as "flight levels" and abbreviated. For example: FL 200 or FL 450.

(c) Distances. All distances shall be expressed in nautical miles and tenths thereof, except when applied to visibilities, which shall be expressed in statute miles and appropriate fractions thereof. Runway Visual Range (RVR) shall be expressed in feet.

(d) Speeds. Aircraft speeds shall be expressed in knots.

(2) Positive Course Guidance. Positive course guidance shall be provided in transition, initial, intermediate, and final approach segments. ASR may be used to provide vectoring to or through any approach segment. ARSR may be used to provide course guidance through initial approach segments up to and including the intermediate way point.

(3) Approach Categories. Aircraft performance differences have a direct effect on the airspace and visibility needed to perform certain maneuvers, such as circle to land, turning missed approaches, final alignment correction to land, and descent. The following categories are established, and will be referred to throughout this publication by their letter designation (A, B, C, D, or E):

(a) Category A. Speed less than 91 knots or weight less than 30,001 lbs.

(b) Category B. Speed 91-120 knots or weight 30,001 - 60,000 lbs.

(c) Category C. Speed 121-140 knots or weight 60,001 - 150,000 lbs.

(d) Category D. Speed 141-165 knots or weight over 150,000 lbs.

(e) Category E. Speed over 165 knots. Weight not considered.

NOTE: Speeds are based on 1.3 times the stall speed in the landing configuration at maximum gross landing weight. Weights are maximum authorized gross landing weights. An aircraft shall fit in only one category, and that category shall be the highest category in which it meets either of the specifications. For example, a 30,000 lb. landing weight aircraft which approaches at 130 knots fits into Category C.

(4) Approach Category Application. The approach category operating characteristics shall be used to determine turning radii, minimums, and obstruction clearance areas for circling and missed approach.

(5) Procedure Construction. An instrument approach procedure may have five separate segments. They are the transition, the initial, the intermediate, the final, and the missed approach segments. In addition, an area for circling the airport under visual conditions shall be considered. The approach segments begin and end at designated way points. The way points are

named to coincide with the associated segment. For example, the intermediate segment begins at the intermediate way point and ends at the final approach way point. The order in which this appendix discusses the segments is the same order in which the pilot would fly them in a completed procedure; that is from a transition or initial, through an intermediate to a final approach. Only those segments which are required by local conditions need be included in a procedure. In constructing the procedure, the final approach course should be identified first because it is the least flexible and most critical of all the segments. When the final approach has been determined, the other segments should be blended with it to produce an orderly maneuvering pattern which is responsive to the local traffic flow. Consideration shall also be given to any accompanying controlled airspace requirements in order to conserve airspace to the extent it is feasible.

(a) Transition Segment (Feeder Routes). The information contained in this paragraph applies equally to low and high altitude procedures. Transitions, when required, are used to designate course and distance from a way point in the en route structure to the initial approach way point (IAWP). Only those transitions which provide an operational advantage shall be established and published. These should coincide with the local air traffic flow. The length of the transition shall not exceed the operational service volume of the facilities which provide navigational guidance unless additional frequency protection is provided. RNAV transitions may be included in conventional approach procedures such as ILS. En route RNAV airway obstruction clearance criteria shall apply to transitions.

(b) Initial Approach.

1 Initial Approach Segment. Although transitions may be prescribed in an instrument procedure, the instrument approach as such commences at the Initial Approach Way Point (IAWP). In the initial approach the aircraft has departed the en route or transitional phase of flight, and is maneuvering to enter an intermediate segment. When the intermediate way point is part of the en route structure it may not be necessary to designate an initial approach segment. In this case the approach commences at the intermediate

way point and intermediate segment criteria apply. An initial approach may be made along a course, or radar vector. Although more than one initial approach may be established for a procedure, the number should be limited to that which is justified by traffic flow or other operational requirements. Where holding is required prior to entering the initial approach segment, the holding way point and initial approach way point should coincide.

2 Altitude Selection. Minimum altitudes in the initial approach segment shall be established in 100-foot increments; i.e., 1549 feet may be shown as 1500 feet and 1550 feet shall be shown as 1600. In addition, altitudes specified in the initial approach segment must not be lower than any altitude specified for any portion of the intermediate or final approach segment.

3 Alignment. The angle of intersection between the initial approach course and the intermediate course shall not exceed 90 degrees. Where necessary, additional way points will be established to eliminate the need for intercept angles greater than 90 degrees, or an initial approach based on course reversal will be provided in accordance with Paragraph 7 below. Where additional way points are established a minimum spacing of five miles between way points should be provided to minimize additional cockpit workload.

4 Area. The initial approach segment has no standard length. The length shall be sufficient to permit the altitude change required by the procedure and shall not exceed 50 miles unless an operational requirement exists. The primary and secondary areas of the initial approach segment are identical to RNAV en route criteria.

5 Obstacle Clearance. The obstacle clearance in the initial approach primary area shall be a minimum of 1000 feet. In the secondary area, 500 feet of obstacle clearance shall be provided at the inner edge, tapering uniformly to zero feet at the outer edge.

6 Descent Gradient. The OPTIMUM descent gradient in the initial approach is 250 feet per mile. Where a higher descent gradient is necessary the maximum gradient is 500 feet per mile.

7 Initial Approaches Based on Course Reversal. Initial approach segments based on a procedure turn shall not be established. Where course reversal is required a holding pattern shall be established in lieu of the procedure turn. Standard holding pattern obstacle clearance shall apply.

(c) Intermediate Approaches.

1 Intermediate Approach Segment.. This is the segment which blends the initial approach segment into the final approach segment. It is the segment in which aircraft configuration, speed, and positioning adjustments are made for entry into the final approach segment. The intermediate segment begins at the intermediate way point (INWP), and ends at the final approach way point (FAWP). Application is similar to typical approach segments contained in FAA Handbook 8230.6 (TERPs).

2 Altitude Selection. The minimum altitude in the intermediate segment shall be established in 100-foot increments; i.e., 749 feet may be shown as 700 feet and 750 feet shall be shown as 800. In addition, the altitude selected for arrival over the FAWP shall be low enough to permit descent from the FAWP to the airport for a straight-in landing whenever possible.

3 Alignment. The course to be flown in the intermediate segment shall be the same as the final approach, except when it is not practical for the courses to be identical. In such cases, the intermediate course shall not differ from the final approach course by more than 60 degrees.

4 Area.

aa. Length. The intermediate segment shall not be less than 5 miles or more than 15 miles in length, measured along the course to be flown. The optimum length is 10 miles. A distance greater than 10 miles should not be used unless an operational requirement justifies a greater distance.

bb. Width. The total width of the intermediate segment is determined by joining the outer edges of the initial approach segment with the outer edges of the final approach segment by means of straight lines. For obstacle clearance purposes, the intermediate segment is divided into a primary and a secondary area. The primary area is determined by joining the primary initial approach area with the primary final approach area by means of straight lines. The secondary area is determined by joining the respective initial approach and final approach secondary areas by means of straight lines.

5 Obstacle Clearance. A minimum of 500 feet of obstacle clearance shall be provided in the primary area of the intermediate approach segment. In the secondary area, 500 feet of obstacle clearance shall be provided at the inner edge, tapering to zero feet at the outer edge.

6 Descent Gradients. Because the intermediate segment is used to prepare the aircraft speed and configuration for entry into the final approach segment the descent gradient should be as flat as possible. The optimum descent gradient in this area should not exceed 150 feet per mile. Where a higher descent gradient is necessary, the MAXIMUM permissable gradient is 300 feet per mile.

(d) Final Approach.

1 Final Approach Segment. This is the segment in which alignment and descent for landing are accomplished. The final approach segment considered for obstacle clearance begins at the final approach way point and ends at the runway or airport. Final approach may be made to a runway for a straight-in landing, or to an airport for a circling approach. Only one final approach shall be specified for a procedure.

2 A minimum of two way points shall be designated, and shall be within 25 miles of the reference facility.

aa. Missed approach way point established at the runway threshold.

bb. Final approach way point established with reference to the length of the final approach segment in accordance with Table No. 1, page 10.

3 Straight-In. The final approach course for RNAV procedures shall be aligned with the runway centerline.

4 Area. The area considered for obstacle clearance in the final approach segment starts at the final approach way point and ends at the missed approach way point. It is made up of primary and secondary areas. The primary area is centered longitudinally on the final approach course. It expands uniformly from the width of the missed approach way point to the width of the final approach way point. A secondary area is on each side of the primary area. It shall be one mile in width. (See Paragraph 7 for way point widths.)

5 Length of Final Approach Segment. The OPTIMUM length of the final approach segment is 5 miles. The MAXIMUM length is 10 miles. The MINIMUM length of the final approach segment shall provide adequate distance for an aircraft to make the required descent, and to regain course alignment when a turn is required over the final approach way point. Table 1 shall be used to determine the minimum length needed to regain the course.

6 Obstacle Clearance - Straight-In Landing. The minimum obstacle clearance in the primary area is 250 feet. In the secondary area 250 feet of obstacle clearance shall be provided at the inner edge, tapering uniformly to zero feet at the outer edge.

APPROACH CATEGORY	Magnitude of turn over the Final Approach Way Point (FAWP) 10°	20°	30°	40°	50°	60°
A	1.0	1.5	2.0	3.0	4.0	5.0
B	1.5	2.0	2.5	3.5	4.5	5.5
C	2.0	2.5	3.0	4.0	5.0	6.0
D	2.5	3.0	3.5	4.5	5.5	6.5

Table 1.

7 Final Approach Way Point and Missed Approach Way Point Area. A circle with a .9-mile radius circumscribed from the plotted position of the way point when within 10 nm of the reference facility expanding uniformly to a 2-mile radius at 25 miles from the reference facility. The lateral dimensions of the final approach segment are established by connecting lines between the missed approach way point and the final approach way point at their points of maximum width.

NOTE: When a turn is required at the final approach way point, a 2-mile radius is required regardless of the distance from the reference facility.

(e) Circling Approach.

1 Circling Approach Area. This is the obstacle clearance area which shall be considered for aircraft maneuvering to land on a runway which does not meet straight-in approach criteria.

2 Alignment and Area. The size of the circling area varies with the approach category of the aircraft, as shown in the table below. To define the limits of the circling area for the appropriate category, draw an arc of suitable radius from the center of the threshold of each usable runway. Join the extremities of the adjacent arcs with lines tangent to the arcs. The area thus enclosed is the circling approach area.

CIRCLING APPROACH AREA RADIUS TABLE.

Approach Category	Radius (Miles)
A	1.3
B	1.5
C	1.7
D	2.3

Table 2.

3 Obstacle Clearance. A minimum of 300 feet of obstacle clearance shall be provided in the circling approach area. There is no secondary obstacle clearance area for the circling approach.

(f) Descent Gradient. The optimum descent gradient in the final approach segment is 300 feet per mile. Where a higher descent gradient is necessary, the MAXIMUM permissable gradient is 400 feet per mile. The descent gradient shall be computed with respect to the length of the final approach segment, using the difference between the altitude over the final approach way point; and,

1 For Straight-In Approach. The elevation of the touchdown zone.

2 For Circling Approach. The circling MDA.

NOTE: Where straight-in descent gradient criteria is exceeded, only circling MDA shall be authorized.

(g) Vertical Guidance. The final approach angle will be computed and published. This describes the angle from the final approach way point altitude to the runway threshold elevation. Obstacle clearance shall not be predicated on use of vertical guidance information at this time. This information is published to provide a constant descent rate from the final approach way point to the runway for aircraft with vertical guidance capability.

(h) Missed Approach Segment. A missed approach procedure shall be established for each procedure in accordance with FAA Handbook 8260.3, (TERPs), Chapter 2, Section 7. Where the MAP way point accuracy (area) exceeds 1 mile, the final approach area shall be extended so as to delay the start of the 40:1 missed approach surface. This surface begins at a point beyond the designated MAP equal to the amount of excessive way point area over 1 mile.

* (i) Approach Minimums.. Approach minimums for non-precision approaches contained in FAA Handbook 8260.3A (TERPs), Chapter 3, Table 9, shall be utilized. However, until operational experience has been gained in the use of the RNAV systems, MDAs will *

* be increased by 200' and visibilities will be increased by ½ mile but not to exceed 2 miles. As soon as data substantiates operational accuracy and reliability TERPs approach minimums will apply. *

(j) All instrument approach procedures shall be flight inspected to ensure that facility performance supports the procedure and that obstacle clearance is satisfactory.

3. IFR FLIGHT PLANNING.

a. Only pilots of aircraft equipped with area navigation equipment approved for IFR operation in accordance with this Advisory Circular may identify this capability when filing an IFR flight plan by appending the AIRCRAFT TYPE with the suffix that also defines the transponder capability as follows:

/C -- no code transponder and area navigation.

/F -- 4096 code transponder and area navigation.

/S -- 64 code transponder and area navigation.

/W -- no transponder and area navigation.

b. When filing an IFR flight plan, area navigation routes or a combination of area navigation routes and VOR airways and routes may be specified for operations at or below FL 450. Area navigation route numbers may be filed in the same manner as VOR airway/route numbers. The filed route should clearly define the intended route during transition from the VOR structure and vice versa. The complexities involved in determining route width, reference facility usable distance and obstruction clearance altitudes make impromptu routes impractical during initial implementation phases of area navigation; therefore, random routes should not be filed and will be approved only in a radar environment based on in-flight requests.

4. ROUTE WIDTH SUMMARY. The Area Navigation Route Width Summary, Figure 1, Page 13, illustrates the effect of total RNAV system accuracies at various angles and distances from the VOR/DME facility and depicts the zones which establish the route width dimensions. Additionally, the examples illustrate the method used to construct RNAV routes taking advantage of the system capabilities.

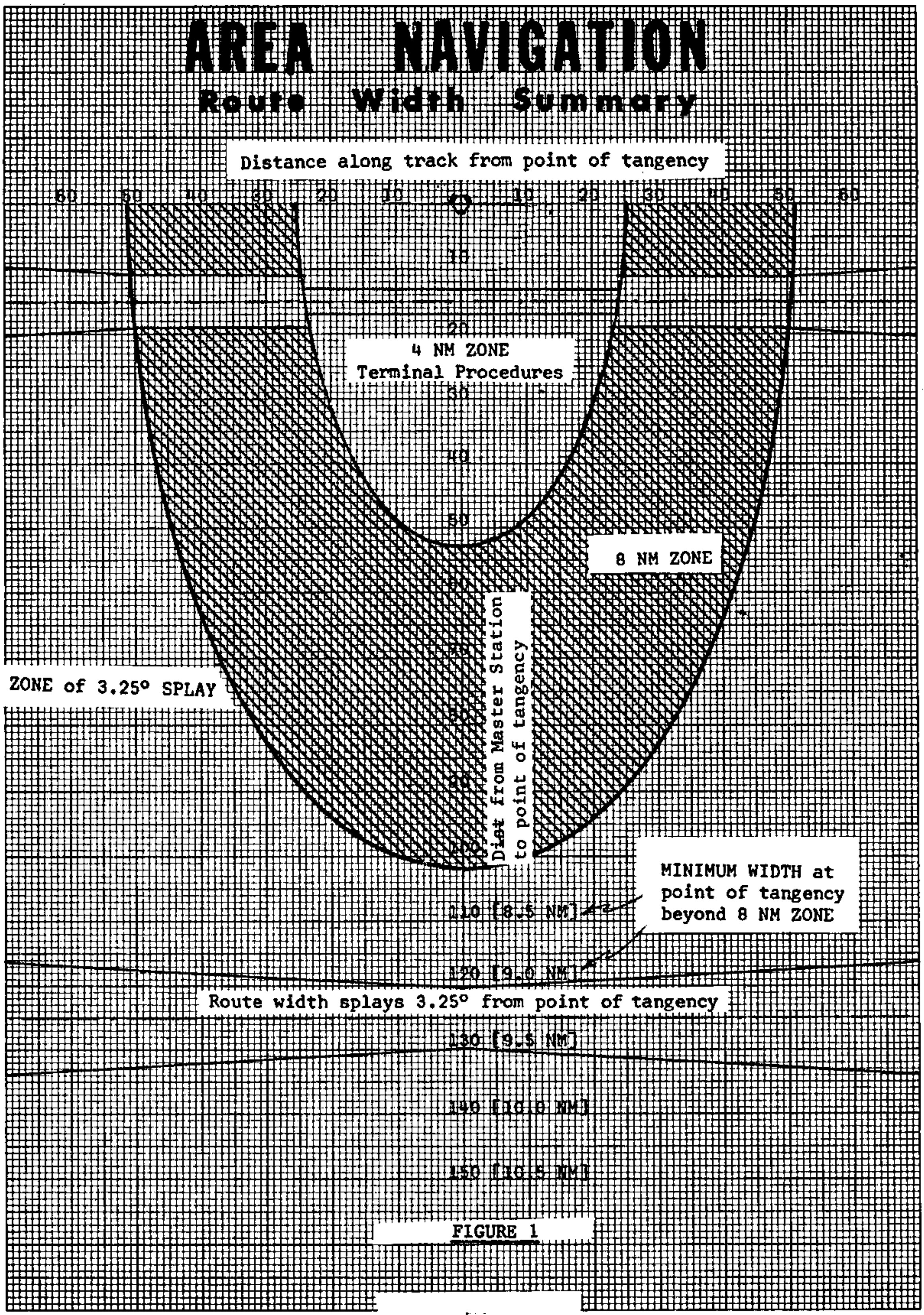

AREA NAVIGATION
Route Width Summary
Distance along track from point of tangency
60 50 40 30 20 10 0 10 20 30 40 50 60
10
20
4 NM ZONE
Terminal Procedures
30
40
50
8 NM ZONE
60
70
ZONE of 3.25° SPLAY
80
90
Dist from Master Station
to point of tangency
100
MINIMUM WIDTH at
point of tangency
beyond 8 NM ZONE
110 [8.5 NM]
120 [9.0 NM]
Route width splays 3.25° from point of tangency
130 [9.5 NM]
140 [10.0 NM]
150 [10.5 NM]

FIGURE 1

APPENDIX E. MAINTENANCE

1. MAINTENANCE. All maintenance will be performed in accordance with FAR 43 and the manufacturer's instructions, or in accordance with a manual under an approved maintenance procedure. Records of maintenance should be entered in the airplane maintenance records required by FAR 43.9, or in the records required by the operator's approved maintenance procedures. Following repair or alteration, the system should be checked before predicating any operation on its use. Compatibility of the airborne area navigation system replacement components should be assured unless the replacement is of the same make and model as those upon which original approval was based.

2. INSPECTION AND TEST PROCEDURES. Operators using aircraft under IFR with an airborne area navigation system and not under an approved maintenance procedure should establish procedures which will be used to inspect and test the equipment periodically to determine that it is operating in accordance with at least the accuracy specified in Appendix A. Such procedures should include a method for analyzing malfunctions and defects to determine that the established inspections and tests give reasonable assurance that the equipment is maintaining its accuracy. Test and inspection procedures and intervals should be adjusted in accordance with the results of the analysis.

APPENDIX F. AIR CARRIERS/COMMERCIAL OPERATORS OF LARGE AIRCRAFT/TRAVEL CLUBS*

1. TRAINING PROGRAM. This type of operator should outline the training program he plans to set up to comply with the referenced FAR 121 parts. Under these rules, the training program is acceptable if:

   a. It encompasses all phases of the operation and fully covers all responsibilities of flight crewmembers, dispatchers and maintenance personnel.

   b. Its technical content for pilots covers:

      (1) Theory and procedures, limitations, detection of malfunctions, preflight and inflight testing, cross-checking methods, etc., relating to the operations; and,

      (2) An operational explanation of all systems, together with a review of navigation and flight planning.

   c. Its recurrent training program includes area navigation training.

   d. Each pilot assigned as an operating crewmember completes as many trips over a route or area (either in actual operation or, in part in an approved simulator or approved procedural trainer or training device) under the supervision of an appropriate instructor or a check airman, as may be necessary to:

      (1) Ensure his qualification in the system; and,

      (2) Enable certification of his proficiency in the system, as required by Section 121.413.

   e. The training program conforms with the above and is approved by a representative of the Administrator.

   *Travel Clubs will conform to the applicable parts of the above training program.

2. OPERATIONS MANUAL. Revisions to the operations manual should be provided outlining all procedures and emphasizing the methods for preflight and inflight test and step-by-step operation of the area navigation equipment. The manual should contain procedures for continuing the flight with partial or complete area navigation equipment failure.

3. MINIMUM EQUIPMENT LIST (MEL). For those components of the area navigation equipment required for area navigation operations, MEL revisions will be needed and operations specifications will so specify. The MEL should permit single system operation in dual system installations.

4. AUTHORIZATION. The operations specifications will contain the authorization to use an area navigation system and identify the airborne equipment.

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

OPERATIONS SPECIFICATIONS - EN ROUTE FLIGHT PROCEDURES

Form Approved
Budget Bureau No. 04-R083.1

ROUTE OR ROUTE SEGMENT	VIA	OPERATION AUTHORIZED				TYPE OF AIRCRAFT AUTHORIZED				SPECIAL REQUIREMENTS				
		DAY		NIGHT		DC-9				MOCA	MEA	MAA	OTHER	TYPE NAVIGATION[1]
		VFR	IFR	VFR	IFR	B-707								
							Note: Both pilots will be RNAV qualified in accordance with approved training programs, except that when navigation is being performed under the supervision of an approved RNAV-qualified check pilot, the pilots performing such supervised navigation need only have satisfactorily completed the approved RNAV ground school curriculum.							RNAV

EFFECTIVE DATE	NAME OF AIR CARRIER
	ABC Airlines, Inc.

[1] Where a navigator or special cockpit navigation and equipment is required, so specify; ie Navigator, Cockpit (Doppler - Loran), (Inertial).
RNAV

FAA Form 8400-1 (10-68)

APPENDIX G. GENERAL AVIATION

1. TRAINING PROGRAM. The operator should become thoroughly familiar with the operation of his area navigation equipment before he uses this equipment in an IFR environment. A recommended training program should:

   a. Encompass all phases of the operation of the area navigation system.

   b. Cover the theory of operation, setting procedures, familiarization, detection of malfunctions, preflight and inflight testing and cross-checking methods.

   c. Include procedures for continuing the flight with partial or complete area navigation equipment failure.

   d. Provide that each operator of area navigation equipment will complete a sufficient number of simulated IFR approaches, missed approaches, departures and en route operations to ensure that he is competent to operate the equipment.

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APPENDIX H. AIR TAXI

1. SCHEDULED AIR TAXIS AND OTHER AIR TAXIS USING LARGE AIRCRAFT

a. TRAINING PROGRAM. This type operator should outline the training program he plans to establish in compliance with the training requirements of his operations specifications. A training program is acceptable if:

(1) It encompasses all phases of the operation and fully covers all responsibilities of flight crewmembers and maintenance personnel.

(2) Its technical content, for pilots, covers:

(a) Theory and procedures, limitations, detection of malfunctions, preflight and inflight testing, cross-checking methods, etc., relating to the operation; and,

(b) An operational explanation of all systems, a review of navigation and flight planning.

(3) Its recurrent training program includes area navigation training.

(4) Each pilot assigned as an operating crewmember completes as many trips over a route or area (either in actual operation or, in part, in an approved simulator or approved procedural trainer or training device) under the supervision of an instructor or a check airman, as may be necessary to:

(a) Ensure his qualification in the system; and,

(b) Enable certification of his proficiency in the system, as required by Section 135.131.

b. OPERATIONS MANUAL. Revisions to the operations manual should be provided outlining all procedures and emphasizing the methods for preflight and inflight test and step-by-step operation of the area navigation equipment. The manual should contain procedures for continuing the flight navigation with partial or complete area navigation equipment failure.

c. AUTHORIZATION. The operations specifications will contain the authorization to use an area navigation system and identify the airborne equipment.

2. AIR TAXIS OTHER THAN SCHEDULED AIR TAXIS AND THOSE USING LARGE AIRCRAFT

a. TRAINING PROGRAM. This type operator should establish a suitable training program to assure thorough familiarity with the operation of area navigation equipment before using it in an IFR environment. The training program should:

(1) Encompass all phases of the operation and fully cover all responsibilities of pilots and maintenance personnel.

(2) Include for pilots:

(a) Theory and procedures, limitations, detection of malfunctions, preflight and inflight testing, cross-checking methods, etc., relating to the operation;

(b) An operational explanation of all systems, a review of navigation and flight planning; and,

(c) Procedures for continuing the flight with partial or complete area navigation equipment failure.

(3) Contain a recurrent training program for area navigation.

(4) Provide that each pilot assigned to flight duty using the area navigation system completes as many flights, under the supervision of an instructor or a check airman, as necessary to:

(a) Ensure his qualification in the system; and,

(b) Enable certification of his proficiency in the system, as required by Section 135.131.

b. AUTHORIZATION. The operations specifications will contain the authorization to use an area navigation system and identify the airborne equipment.

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