U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: AIRWORTHINESS APPROVAL OF MULTI-SENSOR NAVIGATION SYSTEMS FOR USE IN THE U.S. NATIONAL AIRSPACE SYSTEM (NAS) AND ALASKA

Date: 9/12/88
Initiated by: AIR-120

AC No: 20-130
Change:

1. PURPOSE. This advisory circular (ac) establishes an acceptable means, but not the only means, of obtaining airworthiness approval of a multi-sensor area navigation system for use under VFR (visual flight rules) and IFR (instrument flight rules) within the conterminous United States, Alaska, and surrounding United States waters. Like all advisory material, this advisory circular is not, in itself, mandatory and does not constitute a regulation. It is issued for guidance purposes and to outline one method of compliance with airworthiness requirements. As such, the terms "shall" and "must" used in this advisory circular pertain to an applicant who chooses to follow the method presented. The guidelines provided in this advisory circular supersede those of AC 90-45A, Approval of Area Navigation Systems for Use in the U.S. National Airspace System, for the equipment described herein.

2. RELATED FAR. Federal Aviation Regulations (FAR) Parts 23, 25, 27, 29, 43, and 91.

3. RELATED READING MATERIALS.

a. Federal Aviation Administration (FAA)/Technical Standard Order (TSO) C115, Area Navigation Equipment Using Multi-Sensor Inputs. Copies may be obtained from the Department of Transportation, FAA, Aircraft Certification Service, Aircraft Engineering Division (AIR-120), 800 Independence Avenue, SW., Washington, DC 20591.

b. Radio Technical Commission for Aeronautics (RTCA), Document No. RTCA/DO-160B, Environmental Conditions and Test Procedures for Airborne Equipment, Document No. RTCA/DO-178A, Software Considerations in Airborne Systems and Equipment Certification, and Document No. RTCA/DO-187, Minimum Operational Performance Standards for Airborne Area Navigation Equipment Using Multi-Sensor Inputs. Copies may be purchased from RTCA Secretariat, One McPherson Square, Suite 500, 1425 K Street, NW., Washington, DC 20005.

c. Advisory Circular 90-82, Random Area Navigation Routes. Advisory Circular 20-101C, Airworthiness Approval of Omega/VLF Navigation Systems For Use in the U.S. National Airspace System and Alaska. Advisory Circular 20-121A, Airworthiness Approval of Airborne Loran-C Systems For Use in the U.S. National Airspace System and Alaska. Copies may be obtained from the Department of Transportation, Utilization and Storage Section, M-443.2, Washington, DC 20590.

d. Advisory Circular 27-1, Certification of Normal Category Rotorcraft. This document should be referenced to determine if considerations beyond those contained in this advisory circular are necessary when installing a multi-sensor area navigation system in a normal category rotorcraft. If necessary, AC 27-1 will address those items peculiar to rotorcraft installations. Copies may be ordered from: Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, or from any of the Government Printing Office bookstores located in major cities throughout the United States. Identify the publication as AC 27-1, Certification of Normal Category Rotorcraft, Stock Number 050-007-00708-6.

e. Advisory Circular 29-2, Certification of Transport Category Rotorcraft. This document should be referenced to determine if considerations beyond those contained in this advisory circular are necessary when installing a multi-sensor area navigation system in a transport category rotorcraft. If necessary, AC 29-2 will address those items peculiar to rotorcraft installations.

4. BACKGROUND.

a. System Description. Multi-sensor area navigation equipment determines aircraft position by processing data from various position sensors. Aircraft position may be fixed by various methods depending on factors such as availability of sensors, accuracy, signal parameters, location and/or flight phase. Position fixing may employ such sensors as: distance measurements from two or more distance measuring equipment (DME) ground stations (DME-DME), very high frequency range (VOR)/DME, inertial reference unit (IRU), Omega/very low frequency (VLF), Loran-C, and satellite (GPS). These various sensors may be used individually or combined to provide aircraft position. Navigation values such as distance and bearing to a waypoint are computed from the aircraft latitude/longitude and the location of the waypoint. Course guidance is generally provided as a linear deviation from the desired track of a great circle course. The desired course may be pilot selectable or may be determined by the navigation computer by computations based on the locations of successive waypoints.

b. System Availability and Reliability. A multi-sensor navigation system incorporates various position fixing sensors, each of which is individually usable for airborne area navigation.

(1) Omega system status is available from the U.S. Naval Observatory, telephone (703) 866-3801. Omega status messages are also broadcast by the National Bureau of Standards on stations WWV and WWVH at 16 minutes past each hour (WWV) and 47 minutes past each hour (WWVH).

(2) Flight Data Center notice to airmen (NOTAM's) provide information on VOR, DME, Tactical Air Navigation (TACAN), Loran-C, and other navigation systems maintained and operated by the FAA.

(3) Loran-C system status is available by means of telephone data service (300 or 1200 baud, ASCII) from the U.S. Naval Observatory, telephone (202) 653-1079. Ground transmitter reliability exceeds 99 percent annually.

(4) The VLF communications systems operated by the U.S. Navy is not primarily intended for navigation use. The Navy may shut stations down, add new stations, change frequencies, etc., with no advance warning. Information on current VLF system status is not published for the aviation user.

c. General Operational Limitations. Due to the availability and integrity of the various sensor systems, effects of propagation and bias errors, and potential interference with certain sensors from outside sources, certain operational limitations must be imposed on the use of multi-sensor area navigation equipment. These general limitations are as follows:

(1) Operational Areas. Certain sensors, such as Loran C and Omega/VLF, may be limited to use within defined operational areas due to system availability and other factors affecting system performance. The applicant should define the acceptable operating area(s) for each system.

(2) En Route and Terminal National Airspace System (NAS) Use. A multi-sensor area navigation system may be approved for en route and terminal navigation VFR or IFR within the conterminous United States and Alaska. Other navigation equipment (i.e., VOR, DME, TACAN) appropriate to the ground facilities along the intended route to be flown should be installed and operable. En route and terminal accuracy requirements must be met without the need for operator entry of calibration or correction factors.

(3) Approach Use in the NAS. A multi-sensor area navigation system may be approved for instrument approach operations within the conterminous United States and Alaska provided the system is configured to assure approach accuracy requirements are satisfied whenever the approach mode is selected. Operator entry of calibration or correction factors (i.e., Loran-C time difference correction values) shown on a charted instrument approach procedure may be used in satisfying approach accuracy requirements.

(4) IFR Navigation Equipment. Aircraft employing multi-sensor area navigation equipment for IFR navigation should also be equipped with an approved alternate means of navigation.

5. DEFINITIONS.

a. Approach Operations. Approach operations are those flight phases conducted on charted Instrument Approach Procedures (IAP's) commencing at the initial approach fix (IAF) and concluding at landing or the missed approach holding fix, as appropriate.

b. En Route Operations. En route operations are those flight phases conducted on charted VOR routes designated as high or low altitude routes (Jet or Victor), direct point-to-point operations between defined waypoints, or along great circle routes as described in AC 90-82.

c. Precipitation Static (P-Static). P-static is electromagnetic noise generated by the dissipation of an electrical charge from an aircraft into the atmosphere. The aircraft becomes charged by flight through particles suspended in the atmosphere such as dust, ice, rain, or snow. Unprotected aircraft may create so much noise that some receivers can no longer detect the transmitted signal.

d. Terminal Area Operations. Terminal area operations are those flight phases conducted on charted Standard Instrument Departures (SID's), on charted Standard Terminal Arrivals (STAR's), or other flight operations between the last en route fix/waypoint and an initial approach fix/waypoint.

6. AIRWORTHINESS CONSIDERATIONS. Multi-sensor area navigation equipment has been certificated for VFR and IFR use as an area navigation system for en route, terminal and approach navigation in the NAS. This paragraph establishes acceptable criteria for multi-sensor area navigation systems.

a. Multi-Sensor Equipment Installations Used for Operations Under Visual Flight Rules (VFR) Only. Operators wishing to use multi-sensor equipment for operations limited to VFR may obtain approval of the installation by Type Certificate (TC), Supplemental Type Certificate (STC), data field approved by the FAA on an FAA Form 337, Major Repair and Alteration, or by the use of previously approved data. The approval for return to service should be signed by one of the entities noted in FAR 43; i.e., repair station, manufacturer, holder of an inspection authorization, etc. The installation verification should ensure, but is not limited to, the following:

(1) The Multi-Sensor Equipment Installation does not interfere with the normal operation of other equipment installed in the aircraft. This is accomplished by a ground test and flight test to check that the multi-sensor equipment is not a source of objectional electromagnetic interference (EMI), is functioning properly and safely, and operates in accordance with the manufacturer's specifications.

(2) The Structural Mounting of the Multi-Sensor Equipment is sufficient to ensure the restraint of the equipment when subjected to the emergency landing loads appropriate to the aircraft category.

(3) A Navigation Source Annunciator is Provided on or adjacent to the display if the multi-sensor equipment installation supplies any information to displays such as a horizontal situation indicator (HSI) or course deviation indicator (CDI) which can also display information from other systems normally used for aircraft navigation.

(4) The Multi-Sensor Equipment Controls and Displays are Installed with a placard(s) which states "Multi-Sensor Area Navigation Equipment Not Approved for IFR."

(5) The Multi-Sensor Equipment May Be Coupled to the "Radio Nav Function of an autopilot provided the system has a CDI or steering output that is compatible with the autopilot, and the same installation procedures normally used for the VOR coupling are used.

b. Multi-Sensor Equipment Installations Used as an Area Navigation System Under IFR. Criteria for area navigation equipment using multi-sensor inputs are contained in this advisory circular. These criteria are applicable to systems used for flight along published airways, flights on random routes, and non-precision instrument approach operations. Specific guidance information relating to the various sensors providing inputs to the multi-sensor system is found in the respective advisory circular for that system. The initial certification of a multi-sensor system requires an engineering evaluation because of the need to verify accuracy, failure indications, approved operating areas, environmental qualifications, etc. Subsequent installations of the same multi-sensor equipment system in other aircraft may require additional engineering evaluation, depending upon the degree of integration of the system with other aircraft systems. An engineering evaluation will be necessary to change or increase approved operating areas. Multi-sensor area navigation systems for use under IFR should provide the following:

(1) Flightcrew Inputs of:

(i) Aircraft present position in terms of latitude and longitude to at least the nearest 0.1 minute.

(ii) For en route operations, at least three (for to-from equipment) or four (for to-to equipment) waypoint positions in terms of latitude and longitude at least to the nearest 0.1 minute.

(iii) For terminal and approach operations, at least eight (for to-from equipment) or nine (for to-to equipment) waypoint positions in terms of latitude and longitude at least to the nearest 0.1 minute.

(iv) A means to confirm correctness of input data prior to utilization of the new data by the system.

(v) A "direct to" function to define a route segment from present position to any waypoint.

(vi) The capability for operator selection and deselection of any sensor, station, or combination of stations.

NOTE: Waypoints may be entered in terms of bearing and distance from a VOR/DME facility or other waypoint at least to the nearest 0.1 degree and 0.1 nautical mile (nmi).

(2) The System Displays Should Give No Operationally Misleading Information and Should Provide:

(i) Present position in terms of latitude and longitude to at least the nearest 0.1 minute and in terms of magnetic bearing and distance to or from a waypoint to at least the nearest 0.1 nmi and nearest degree. Distances of at least 260 nmi should be capable of being displayed, but distances greater than 99.9 nmi need only be displayed to the nearest nautical mile.

(ii) Waypoint position designation in terms of latitude and longitude to at least the nearest 0.1 minute or in terms of magnetic bearing and distance from present position or another waypoint. Waypoint designation in terms of magnetic bearing and distance should be to at least the nearest degree of bearing and 0.1 nmi for distances up to 100 nmi then at least 1.0 nmi for distances of 100 nmi or more.

NOTE: Information should be provided to the flight crew to prevent the designation of waypoints by a sequence of bearings and distances (i.e., the reference position for a waypoint designated by bearing and distance should be designated by latitude and longitude).

(iii) A display of active waypoint(s) identification (not necessarily waypoint position) used to define the navigation track being flown.

NOTE: Only systems which define the desired navigation track in terms of its endpoints can be used to navigate on published airways due to changes in magnetic variation after the commissioning of the ground facility. Some systems may incorporate magnetic declination of specific ground facilities in their data base to alleviate this situation.

(iv) A display of the desired track in terms of the appropriate magnetic course to at least the nearest 1.0 degree. Display of the appropriate magnetic course should not require the flightcrew to input the magnetic variation corresponding to the present position.

(v) A display of the distance to the active waypoint to the nearest 0.1 nmi. Distances of at least 260 nmi should be capable of being displayed, but distances greater than 99.9 nmi need only be displayed to the nearest 1.0 nmi.

(vi) A continuous analog (i.e., nonnumeric) display of crosstrack deviation with

	En Route/Terminal (nmi)	Approach (nmi)
Minimum Full-Scale Deflection	$\geq$5.0	* $\geq$1.25
Readability	$\leq$1.0	$\leq$0.25
Minimum Discernable Movement	$\leq$0.1	$\leq$0.05

* NOTE: Smaller values of minimum full-scale deflection for approach may be acceptable provided the proposed value is found satisfactory by an engineering evaluation.

NOTE: An appropriately configured electronic map display may be used in place of the crosstrack deviation scale specified provided an engineering evaluation determines it provides an equivalent display of crosstrack deviation.

(vii) For en route and terminal modes, a display of crosstrack deviation to the nearest 0.1 nmi up to 9.9 nmi and 1.0 nmi beyond, with a range of at least ±20 nmi. This may be a digital display, may be pilot selectable, and need not be part of the course deviation indicator. If provided for the approach mode, the display shall provide crosstrack deviation to the nearest 0.1 nmi.

(viii) A display of the distance and magnetic bearing (at the "from" end of the segment) between waypoints to at least the nearest 1.0 nmi and 1.0 degree.

(ix) The capability to indicate, on demand, the specific sensors and/or stations currently used in the navigation calculations as well as the status of all sensors and/or stations being tracked.

(x) An annunciation of impending waypoint crossing.

(3) Caution Indication(s) for the System Should Be Located on or near the indicator specified in paragraph 6b(2)(vi) and should provide a readily discernible caution indication(s) to the pilot(s) for any of the following:

(i) Inadequate or invalid navigation signals or sources.

(ii) The absence of primary power.

(iii) Inadequate or invalid navigation displays or output sources. In the approach mode, the inability to assure navigation position data accurate to within ±0.3 nmi.

(iv) Equipment failures.

(v) Reversion to a secondary dead reckoning mode of navigation.

NOTE: These failure/status indications shall occur independently of any operator action. Power or navigation equipment failures may be indicated in a common manner. The lack of adequate navigation signals or sources (considering signal to noise ratio (SNR) as well as geometry) should be annunciated when compliance with the navigation accuracy specified in paragraph 8 cannot be assured. In the approach mode, the lack of adequate navigation signals or sources shall be annunciated by means of a flag displayed on the primary navigation display. In other modes, an appropriately located annunciator may be used.

(4) The System Shall Be Capable of Providing the Aircraft Position to the accuracy specified in paragraph 8 within 20 seconds after tuning a navigation ground facility (assuming sensor outputs are available).

(5) The System Shall Be Capable of Providing Aircraft Position to the accuracy specified in paragraph 8 within 20 seconds following a mode transition from one set of sensors to another or one method of position fixing to another (assuming sensor outputs are available).

(6) Navigation Guidance Should Be Available within 5 seconds of waypoint data input.

(7) The Equipment Should Have the Capability to meet the criteria outlined in paragraph 6b(1) through 6b(6) throughout the range of environmental conditions which will be encountered in actual service. Exposure of the equipment to the environmental test conditions of TSO-C115 may be used to demonstrate this capability.

(8) The Equipment Should Provide a Means for the Flightcrew to determine system status prior to flight.

(9) The Equipment Should Provide the Navigation Accuracy specified in paragraph 8 for all groundspeeds up to a maximum value to be set by the manufacturer and should provide usable navigation information necessary for holding patterns conducted with standard rate turns at speeds up to 250 knots groundspeed or at a lessor value specified by the equipment manufacturer.

(10) The Equipment Should Provide Means to Alert the Flightcrew prior to arrival at a waypoint to permit turn anticipation in accordance with the approximate formula of 1.0 nmi for each 100 knots of groundspeed. This indicator should be located on or near the indicator specified in paragraph 6b(2)(vi). For multi-sensor systems which are not coupled to a flight director or autopilot, a procedural means based on a continuous and properly located distance to waypoint display may be used for waypoint lateral maneuver anticipation. Systems which provide steering signals for flight directors or autopilots should provide automatic turn anticipation and a waypoint alert which occurs prior to the initiation of the turn by the flight director or autopilot.

(11) If a Capability for Parallel Offset Tracks is Provided, track selection should be in increments of at least 1.0 nmi left or right up to an offset of at least 20 nmi. Means should be provided to continuously indicate that an offset track has been selected. Waypoint alerting and turn anticipation should be provided prior to arrival at the point where the offset intersects the angle bisector of the parent track. These functions should operate as described in paragraph 6b(10).

c. Software Changes. The provisions of this paragraph apply to multi-sensor equipment which utilizes a digital computer to provide navigation information or system monitoring. The computer program (software) operates the computer and provides the basic functions of these systems. The software for navigation functions of multi-sensor equipment described in paragraph 6b (for multi-sensor area navigation equipment used for IFR operations) should be verified and validated to at least the level 2 requirements as defined by RTCA/DO-178A. Any changes to software which affects navigational functions are considered to be major changes to the equipment. Unless software partitioning has been previously established, any change to level 1 or level 2 software of multi-sensor area navigation equipment should be verified and validated to the appropriate level and should be demonstrated as not having inadvertently affected the remaining navigational functions. Changes to software used for multi-sensor equipment limited to VFR use or equipment having established partitioning from software which provides navigational functions in IFR systems are considered to be minor and do not require prior approval by the FAA, providing the manufacturer of the multi-sensor equipment has a software configuration management and quality assurance plan approved by the FAA. Software status must be identified on the outside of the associated line replaceable unit in accordance with the criteria of RTCA/DO-178A. Software changes in TSO approved equipment must be reported to the cognizant Aircraft Certification Office. If the equipment displays a software identifier to the flightcrew, the airplane or rotorcraft flight manual (or appropriate placard) should indicate the approved identifier. Software changes incorporated in equipment already installed in an aircraft may require additional evaluation and possible flight manual supplement revision prior to returning the aircraft to service, depending upon the scope of the change.

7. EQUIPMENT INSTALLATION CONSIDERATIONS FOR USE UNDER IFR.

a. Location of the Multi-Sensor System Displays. Each display element, used as a primary flight instrument in the guidance and control of the aircraft, for maneuver anticipation, or for failure annunciation, should be located where it is clearly visible to the pilot (in the pilot's primary field of view) with the least practicable deviation from the pilot's normal position and line of vision when looking forward along the flight path.

b. Failure Protection. Any probable failure of the airborne multi-sensor navigation system should not degrade the normal operation of other required equipment or create a flight hazard. Normal operation of the multi-sensor equipment installation should not adversely affect the performance of other aircraft equipment.

c. Environmental Conditions. The aircraft environment in which the multi-sensor system is installed should be found to be compatible with environmental categories to which the equipment was tested.

d. Electromagnetic Interference. The multi-sensor navigation system should not be the source of objectionable electromagnetic interference, nor be adversely affected by electromagnetic interference from other equipment in the aircraft.

e. P-Static Protection. If an E-Field antenna (whip, plate, or blade type) is used (such as with an Omega/VLF or Loran-C sensor), the aircraft should be protected by acceptable bonding techniques and installation of static dischargers. These protective devices should be specified as part of the approved design data for the multi-sensor installation. The capability to provide satisfactory P-static protection for the system should be demonstrated as part of the initial certification program. This testing may be accomplished by ground or static testing if sufficient data is provided to demonstrate that the proposed technique is equivalent to flight testing. If a flight demonstration is selected, it must be conducted at speeds up to V_{ne}, V_{mo}, or M_{mo} through known P-static conditions such as a cloud of ice crystals. Momentary loss of signal when encountering heavy P-static conditions may be acceptable provided the equipment is capable of providing acceptable navigation information during such conditions.

(1) P-Static Charging/Discharging. P-static charging of the aircraft can cause degradation of the signal-to-noise ratio by one of three major mechanisms: sparkover of isolated metal panels, corona discharge, and streamer currents. Sparkover of isolated metal panels can be handled by appropriate bonding. This bonding needs to occur on all control and trim surfaces as well as isolated access panels. Bonding should be evaluated by a careful ohmic survey (an electrical bonding limit of 10 milliohms is considered acceptable) of each aircraft in which the multi-sensor system is installed or by other suitable techniques. The effects caused by streamer currents can be reduced by placing the receiving antenna as far as possible from any nonconductive surfaces such as windshields. The nonconductive surfaces may be coated with a conductive coating. Temporary spray coatings are not satisfactory. Corona discharge can be reduced by the appropriate placing of orthodecoupled static dischargers on the extremities of the aircraft. A number of recent studies have shown that the frayed-wick types of discharger rapidly lose their effectiveness as a result of use. Therefore, dischargers constructed with a high resistance rod and metal pins are recommended although other types may also be used if they can demonstrate ability to provide protection from radio frequency (RF) coupling to the sensor antenna. The number, type, and location of these static dischargers to be installed on a particular aircraft model should be determined by following the instructions provided by the manufacturer of the static discharger for P-static protection.

f. Anti-Ice Protection. If the aircraft in which the multi-sensor equipment is installed is approved for flight into known icing conditions, the antenna should have anti-ice protection or be found not to be susceptible to ice buildup. Alternatively, if the multi-sensor system can be shown to operate satisfactorily when the antenna(s) is subject to icing, or if the system is limited via placard or flight manual to indicate that it is not to be used for navigation during flight in icing conditions, then anti-ice protection is not required.

g. Dynamic Responses. The system shall continue to indicate aircraft position to the accuracy specified in paragraph 8 during aircraft maneuvering or changes in attitude encountered in normal operations, assuming secondary inputs are not lost during the maneuver.

h. System Controls. The system controls should be arranged to provide adequate protection against inadvertent system turnoff. The controls for system operation should be readily accessible to, and usable by, the flightcrew and be visible under all expected lighting conditions, including night and direct sunlight.

i. System Tests. The initial approval of a multi-sensor area navigation system for IFR use involves extensive testing to demonstrate system performance, operational areas, environmental qualifications, etc., as described in paragraph 6b(7). Subsequent installations in other aircraft need only be tested to the extent necessary to demonstrate proper operation of interfacing aircraft equipment such as autopilots, flight directors and instrument displays, satisfactory antenna installations as evidenced by the reception of Omega/VLF, Loran-C, VOR, DME, etc., signals during normal flight maneuvers, satisfactory clearance of electromagnetic interference (EMI), and functional check of the multi-sensor equipment.

j. Manufacturer's Instructions. Multi-sensor area navigation equipment should be installed in accordance with instructions and limitations provided by the manufacturer of the equipment.

8. SYSTEM ACCURACY.

a. En route IFR Operation Along Random (Off Airways) Area Navigation (RNAV) Routes with Radar Coverage. The error of the airborne multi-sensor equipment should be less than ±3.8 nmi of crosstrack error on a 95 percent probability basis and ±3.8 nmi of along-track error on a 95 percent probability basis.

b. En route IFR Operation on Airways in the NAS. The error of the airborne multi-sensor equipment should be less than ±2.8 nmi of cross-track error on a 95 percent probability basis and ±2.8 nmi of along-track error on a 95 percent probability basis for approval of en route IFR operations on airways.

c. Terminal IFR Operation in the NAS. The error of the airborne multi-sensor equipment should be less than ±1.7 nmi of crosstrack error on a 95 percent probability basis and ±1.7 nmi of along-track error on a 95 percent probability basis for approval of terminal IFR operations.

d. Instrument Approach Operation in the NAS. The error of the airborne multi-sensor equipment should be less than ±0.3 nmi (±0.5 nmi for navigation data derived from a single collocated VOR/DME station) of crosstrack error on a 95 percent probability basis and ±0.3 nmi (±0.5 nmi for navigation data derived from a single collocated VOR/DME station) of along-track error on a 95 percent probability basis for approval of instrument approach operations.

e. Flight Technical (Pilotage) Errors. With satisfactory displays of crosstrack position, the FAA has determined that flight technical errors can be expected to be less than the values shown below on a two-sigma basis.

Flight Condition	Flight Technical Error
En route	±1.0 nmi
Terminal	±1.0 nmi
Approach	±0.5 nmi

Sufficient flight tests of the installation should be conducted to verify that these values can be maintained. Smaller values for flight technical errors should not be expected, unless the multi-sensor system is to be used only when coupled to an autopilot; however, at least the total system crosstrack accuracy shown below should be maintained.

If an installation results in larger flight technical errors, the total crosstrack error of the system should be determined by combining equipment and flight technical errors using the root sum square (RSS) method. The result should be less than the values listed below.

Flight Condition	Total Crosstrack Error
Random RNAV Routes	±4.0 nmi
En route, on Airways	±3.0 nmi
Terminal	±2.0 nmi
Approach (other than single VOR/DME)	±0.6 nmi
Approach (single VOR/DME)	±0.7 nmi

9. IFR AIRWORTHINESS APPROVAL. There are two types of approval which differ greatly as to test requirements and data analysis.

a. First-Time Airworthiness Approval. This type of approval refers to the very first time an applicant presents a particular model multi-sensor equipment for FAA airworthiness installation approval and certification for an IFR navigation system. Any new models of multi-sensor equipment by the same manufacturer should undergo the same approval process as the original equipment unless it can be shown by analysis and tests that the new model will function as well or better than the approved equipment. A first-time approval is conducted in three phases:

(1) Lab/Bench Tests and Equipment Data Evaluation. This phase consists of the following:

(i) Analysis of the manufacturer's procedures for verification and validation of software and review of supporting documentation in accordance with the guidelines of RTCA/DO-178A where the system performs navigational functions.

(ii) Verification of compliance with appropriate environmental qualification standards such as RTCA/DO-160B.

(iii) Examination of the equipment's display capabilities with emphasis on warning, caution, and advisory annunciations.

(iv) Analysis of failure modes.

(v) Review of reliability data to establish that all probable failures are detected.

(vi) Evaluation of the ease of use of the controls and of the viewing ease of the displays and annunciations from a human factors point of view.

(vii) Review of installation and maintenance manuals.

(viii) Evaluation of operator's manual (pilot's guide).

(2) Aircraft Installation Data Evaluation. Normally the manufacturer of the multi-sensor equipment will provide an aircraft as a test bed for a first-time installation approval. This first-time installation approval will serve as a basis for any subsequent installation approvals regardless of aircraft type or model. The following assessments are to be made:

(i) Review of installation drawings, wiring diagrams, and descriptive wiring routing.

(ii) Evaluation of the cockpit layout of the installed equipment with emphasis on equipment controls, applicable circuit breakers (labels and accessibility), switching arrangement and related indicators, displays, annunciators, etc.

(iii) Analysis of a data flow diagram in order to review which equipment transmits what data to which other equipment.

(iv) Review of a structural analysis of the equipment installation in order to ascertain whether all system components are satisfactorily attached to the basic aircraft structure.

(v) Examination of an electrical load analysis in order to verify that the added electrical power requirements of the system installation will not cause overloading of the aircraft's electrical generating capacity.

(vi) Evaluation of the antenna installation. A critical aspect of any multi-sensor system installation is the installation of the antenna(s). The various sensors may operate from signals that are quite weak, typically only one-third the value of the background noise. Electrical noise in the vicinity of the antenna can render such sensors useless.

<u>A</u> E-Field antenna (whip, plate, or blade type). Precipitation static has an adverse effect upon the signal receiving capability of this type of antenna. The adverse effects of precipitation static can be minimized by use of the proper antenna type and location, by installation of high-quality static dischargers, by proper bonding, and by application of anti-static paint on all plastic nonconducting surfaces. The manufacturer's installation or maintenance manual usually describes "good" E-Field antenna installation practices.

<u>NOTE</u>: Each aircraft should be subjected to a careful ohmic survey of bonding (an electrical bonding limit of 10 milliohms is considered acceptable). The P-static protection is a required part of the system installation and must be maintained for proper system operations.

<u>B</u> H-Field antenna (loop type). The signal receiving quality of this type of antenna is adversely affected by aircraft electrical skin currents, particularly by 400 Hz ac. P-static has no appreciable effect on an H-Field antenna, and its effects can usually be ignored. A procedure called "skin mapping" is normally employed to determine a good mounting location. It should be noted that shifting major aircraft electrical components to different locations within the aircraft may render a previously determined skin map location unsuitable.

<u>NOTE</u>: The following is a simple test to verify the effectiveness of an H-Field antenna installation located by skin mapping. Park the aircraft away from any external electrical noise source. Using only the aircraft's battery, and with all other electrical equipment off, activate the multi-sensor equipment and record signal-to-noise values (or quality factors) for all receivable stations

(Omega/VLF and/or Loran-C). Repeat this process of recording signal-to-noise values (or quality factors) with engine(s) running and all electrical/electronic equipment operating on aircraft power. If the antenna installation is satisfactory, there should not be any significant degradation in signal-to-noise ratio values or quality factors.

(3) Flight Test Evaluations. Flight tests are conducted in two stages:

(i) Functional Flight Tests Consist of:

A Evaluation of all operating modes of the multi-sensor equipment.

B Examination of the interface (function) of other equipment connected to the multi-sensor area navigation system.

C Review of various failure modes and associated annunciations such as loss of electrical power, loss of signal reception, multi-sensor equipment failure, etc.

D Evaluation of steering response while autopilot is coupled to the multi-sensor equipment during a variety of different track changes.

E Evaluation of displayed multi-sensor navigation parameters on interfaced flight deck instruments such as HSI, CDI, etc.

F Assessment of all switching and transfer functions pertaining to the multi-sensor equipment installation including high-power electrical loads and electrical bus switching.

G Evaluation to determine whether there exists any electromagnetic or radio frequency interference between the multi-sensor equipment installation and other onboard equipment, or vice versa.

H Evaluation of the acessibility of all controls pertaining to the multi-sensor system installation.

I Evaluation of the visibility of the displays and annunciators pertaining to the multi-sensor system installation during day and night lighting conditions. No distracting cockpit glare or refections may be introduced.

J Analysis of crew workload when operating the multi-sensor equipment.

K Evaluation of diurnal effects (for systems incorporating Omega/VLF sensors).

(ii) Determination of Navigation Error Flight Test. The initial certification of each multi-sensor area navigation system to be used for IFR operations should be based on a demonstration of system accuracy by recording the multi-sensor equipment position and comparing it to the actual position of at least 100 locations distributed throughout the intended operational area. These measures should be recorded in flight by overflight of a known ground reference point at low altitude (less than 3,000' above ground level (AGL)) or comparison with a good multiple DME fix. The data should demonstrate that the appropriate accuracy criteria of paragraph 8 are met on a 95 percent probability basis. Flights into known poor signal areas should be conducted to verify that the caution indications for bad geometry and poor signal quality function properly. A ground or flight test for P-static protection, if appropriate, should be conducted. Normal flight manuevers should not cause loss of system sensor inputs and the system dynamic response should be confirmed. Any unusual flight technical errors or errors resulting from use of the autopilot and flight director should be evaluated and examined. At least 25 percent of the accuracy measurements should be accomplished using degraded system configurations (Omega only, Loran-C only, etc.). An additional 25 percent of the accuracy measurements should be accomplished in areas of marginal performance for the various sensors. The system should demonstrate its ability to re-acquire sensor signals after power interruption in degraded system configurations and in areas of marginal performance for the various sensors.

b. Follow-On Airworthiness Installation Approvals. This type of approval refers to installation approvals in any model or type of aircraft after a first-time airworthiness approval of the particular multi-sensor area navigation equipment has been issued. Follow-on approvals may use the first-time airworthiness approval, which was either a TC or an STC, as a basis for installation approval. Follow-on installation approvals may be accomplished by TC or STC, or may be in the form of a field approval on an FAA Form 337 provided the follow-on installation is in the same type of aircraft that has previously been approved via the TC or STC process and that no new sensors are added to the system. The applicant or installing agency requesting a follow-on multi-sensor system installation utilizing this method of data approval should:

(1) Contact either the manufacturer or organization responsible for obtaining the first-time airworthiness approval in order to:

(i) Obtain a sample airplane flight manual (AFM) or rotorcraft flight manual (RFM) supplement (or supplemental flight manual, as appropriate).

(ii) Obtain verification of the equipment approval status, including the model of the antenna and software program identification.

(iii) Discuss any problem areas and seek assistance in their solution.

(2) Conduct a similar data evaluation as outlined in paragraph 9a(2).

(3) Conduct flight evaluations similar to the flight tests outlined in paragraph 9a(3)(i).

(4) Verify that the ohmic bonding check of the aircraft has been conducted and that appropriate numbers and types of static dischargers are installed if an E-Field antenna is used, or that a skin map has determined the appropriate location for the antenna if an H-Field antenna is used.

(5) Verify that the maximum expected groundspeed of the aircraft is less than the maximum operating speed for which the multi-sensor equipment is qualified.

(6) Spot-check navigation accuracy and verify proper system operation by conducting an evaluation flight. The flight test should be of sufficient length and should follow a plan which permits proper functional evaluation of the multi-sensor system installation. Accuracy should be verified by conducting at least two low-level overflights of known landmarks (i.e., a VOR station). (A DME-DME position fix may be substituted for one of the low-level overflights.) During this flight, the most significant (to navigation) sensors/stations should be deselected approximately 50 percent of the time. The purpose of this test flight is not to validate navigation error values, but rather to verify that in the course of this installation nothing was done to compromise the accuracy of the system as determined by the first-time approval. Errors in excess of the values listed in paragraph 8 should be evaluated to determine possible causes. If a logical explanation is not available, additional flight test data points should be collected in the area(s) where the excessive error occurred. If such error(s) persists, approval of the installation should be withheld.

10. OPERATIONAL CONSIDERATIONS.

a. Operation in the NAS. The aircraft should have navigational equipment installed and operating appropriate to the ground facilities to be used (not including Omega/VLF and/or Loran-C systems). Within the conterminous United States, this requirement may be met with the installation of a VOR receiver in addition to the multi-sensor system approved for IFR operation.

b. Operational Area. Operators and their flightcrews should consult the approved flight manual supplement for their aircraft to determine approved operational areas that may apply to particular systems and/or sensors. Flightcrews must be aware that operational areas for different system/sensors may be different, and the appropriate operating area(s) for a particular system can only be determined by reference to the approved flight manual or other FAA approved documents.

Thomas E. McSweeny

Thomas E. McSweeny
Acting Deputy Director, Aircraft
Certification Service

APPENDIX 1. PROCEDURES FOR OBTAINING FAA APPROVAL FOR IFR/VFR OPERATIONS BY SUPPLEMENTAL TYPE CERTIFICATE OR FAA FORM 337 (FIELD APPROVAL) FOR FOLLOW-ON INSTALLATIONS.

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

a. The STC Applicant:

(1) Makes an application for an STC at the appropriate FAA Aircraft Certification Office. Early contact is wise, since scheduling may be critical. FAA evaluates the data submitted by the applicant, issues a Type Inspection Authorization (TIA), and participates in ground/flight tests outlined in paragraph 9. An STC is issued when all airworthiness requirements are met. If the submitted data is adequate, the STC authorizes identical installations in the same aircraft type.

(2) Designs and installs the multi-sensor system to the criteria set forth in applicable paragraphs of this advisory circular, or consistent with other data acceptable to the Administrator.

(3) Obtains an authorization from the equipment manufacturer to reference the original data for equipment accuracy (per paragraph 8), or conducts the necessary tests.

(4) Makes an aircraft available (with the multi-sensor system installed) for ground inspection and flight test. The applicant is responsible for furnishing a qualified flightcrew for the required flight tests.

(5) Should Submit the following kinds of data for FAA airworthiness evaluation:

(i) Equipment data such as:

(A) Equipment schematics and system wiring diagrams.

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

(C) Equipment manufacturer's quality control procedures (not required if manufacturer's quality control is FAA approved).

(D) Environmental test data.

NOTE: Equipment data need not be submitted if the equipment has been manufactured under technical standard order authorization (TSO C115).

(ii) Fault analysis covering installation.

(iii) Installation information and/or photographs, including antenna and P-static protection devices.

(iv) Structural substantiation as necessary.

(v) Installation wiring diagrams.

(vi) Flight manual supplement or placard drawings as required (see paragraph 2c of this appendix).

(vii) Evidence of previously approved data.

(viii) Electrical load analysis.

b. The Equipment Manufacturer Can Certify (to the applicant and FAA) that the accuracy criteria in paragraph 8 are satisfied by reference to the original approval, a TSO has been obtained, and that the appropriate environmental tests have been conducted.

2. APPROVAL OF TECHNICAL DATA/INSTALLATION FOR IFR OPERATIONS BY FAA FORM 337 (FIELD APPROVAL).

a. Data Submitted by the Applicant. Alteration data for the equipment installation will be submitted with a properly executed FAA Form 337, and a certification from the manufacturer to confirm that the system accuracy requirements of paragraph 8 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/installation, the applicant may also be required to furnish a copy of the equipment data (for equipment not produced under a TSO authorization), manufacturer's operating and installation instructions, fault analysis for installation, installation details and/or photographs, substantiation of structural changes, and system wiring diagrams.

c. Airplane Flight Manual (AFM) or Rotorcraft Flight Manual (RFM) Supplement. An AFM/RFM supplement (or supplemental flight manual) prepared by the applicant and containing the following information must be presented for FAA approval.

(1) Equipment operating limitations.

(2) Emergency/abnormal operating procedures (if applicable).

(3) Normal procedures for operating the multi-sensor area navigation system and any interfaced equipment.

(4) Procedures for verifying proper operation after power outages.

d. The Applicant Makes an Aircraft Available (with the multi-sensor system installed) for ground and flight tests, and is responsible for furnishing a qualified flightcrew for the required flight test. The results of the flight test should be made a part of the data submitted. The FAA approving inspector will request to observe the flight test.

NOTE: The FAA inspector will evaluate and sign the airplane flight manual supplement or rotorcraft flight manual supplement (or supplemental flight manual) presented by the applicant as part of a field approval. Generally, FAA inspectors should have sufficient understanding of the AFM or the RFM to approve a supplement for the multi-sensor system installation without need for engineering assistance. However, if engineering assistance is needed then the inspector should request it early in the program.

e. Field Approvals of Multi-Sensor System Installations for IFR should be limited to follow-on installations where the aircraft is of the same type in which the system was previously approved through the TC or STC process, where no new sensors are added to the system, and where the system installation is either of the stand-alone kind or where the interfaces with autopilot, flight director, and aircraft equipment is of a simple nature. For example, a simple interface is one which provides a switching arrangement to substitute the multi-sensor deviation and flag signals for the comparable outputs of one VOR receiver. Field approvals without engineering assistance should not be made when:

(1) The multi-sensor equipment transfers or accepts data from navigation systems, sensors, or computers other than those previously approved with the particular system;

(2) The aircraft has numerous sources of navigation information installed with a complex-switching system; and

(3) The multi-sensor area navigation system incorporates a software configuration that has not been FAA approved.

3. APPROVAL OF INSTALLATION FOR VFR OPERATIONS. Approval of multi-sensor system installations for operations under VFR may be obtained by TC, STC, or data field approved by the FAA on an FAA Form 337. If previously approved data is available or the installation can be accomplished by utilizing provisions provided by the airframe manufacturer for standard avionics equipment installations, the installation can then be approved for return to service signed by one of the entities noted in FAR 43; i.e., repair station, manufacturer, holder of an inspection authorization, etc., provided the installation:

a. Conforms to the acceptable methods, techniques, and practices contained in AC 43.13-1A, Acceptable Methods, Techniques and Practices--Aircraft Inspection and Repair and AC 43.13-2A, Acceptable Methods, Techniques and Practices-- Aircraft Alterations.

b. Does not interfere with the normal operation of other equipment installed in the aircraft. This is accomplished by a ground test and flight test to check that the multi-sensor equipment is not a source of objectional electromagnetic interference (EMI), is functioning properly and safely, and operates in accordance with the manufacturer's specifications.

c. Does not involve complex switching or integration with other aircraft systems; e.g., flight directors, electronic flight instrument system (EFIS) displays, etc. The multi-sensor system may be coupled to the radio nav function of an autopilot provided it has a course deviation indicator output that is compatible with the autopilot and the same installation procedures normally used for the VOR coupling are used.

d. Provides a navigation source annunciator on or adjacent to the display if the multi-sensor equipment installation supplies any information to displays such as an HSI or CDI which can also display data from other equipment normally used for aircraft navigation.

e. Except for items c and d of this paragraph, is completely isolated from all IFR systems.

f. Has an approval recordation contained in an FAA Form 337 and that a placard in clear view of the pilot which states "Multi-Sensor Area Navigation System Not Approved For IFR."

NOTE: Helicopters approved only for VFR operations do not need placarding.

APPENDIX 2. SAMPLE AIRPLANE FLIGHT MANUAL SUPPLEMENT.

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123 Fourth Street Anytown, USA

FAA APPROVED AIRPLANE FLIGHT MANUAL SUPPLEMENT
MULTI-SENSOR AREA NAVIGATION SYSTEM

AIRPLANE MAKE:

AIRPLANE MODEL:

AIRPLANE SERIAL NUMBER:

AIRPLANE REGISTRATION NUMBER:

This document must be carried in the airplane at all times. It describes the operating procedures for the ______ Multi-Sensor Area Navigation System when it has been installed in accordance with (manufacturer's installation manual) and FAA Form 337 dated ________________________.

For airplanes with a Pilot's Operating Handbook and/or FAA approved Airplane Flight Manual, this document serves as the FAA approved ______ Multi-Sensor Area Navigation System Flight Manual Supplement. When the ______ Multi-Sensor Area Navigation System is installed in an airplane that does not have an FAA approved Airplane Flight Manual, this document serves as the FAA approved Supplemental Flight Manual.

The information contained herein supplements or supersedes the basic Airplane Flight Manual only in those areas listed herein. For limitations, procedures, and performance information not contained in this document, consult the basic Airplane Flight Manual (if applicable).

FAA APPROVED: ______________________________
(Inspector's Name)
Aviation Safety Inspector (Avionics)
ACE-GADO/ACDO/FSDO #_________
Federal Aviation Administration

FAA APPROVED
DATE:____________________

INSTALLATION CENTER/FAA REPAIR STATION #________________
123 Fourth Street
Anytown, USA

FAA APPROVED AIRPLANE FLIGHT MANUAL SUPPLEMENT
MULTI-SENSOR AREA NAVIGATION SYSTEM

SECTION 1

INTRODUCTION

A. EQUIPMENT DESCRIPTION

Provide a general description of the Multi-Sensor Area Navigation System installed in the aircraft.

B. GENERAL

Provided the ______ Multi-Sensor Area Navigation System is receiving adequate usable sensor inputs, it has been demonstrated capable of and has been shown to meet the accuracy specifications of:

1. VFR/IFR enroute, terminal and approach RNAV operation within the conterminous United States and Alaska in accordance with the criteria of AC 20-130.

2. Flight in the North Atlantic (NAT) Minimum Navigation Performance Specifications (MNPS) airspace in accordance with AC 91-49.

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DATE: __________

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FAA APPROVED AIRPLANE FLIGHT MANUAL SUPPLEMENT
MULTI-SENSOR AREA NAVIGATION SYSTEM

SECTION II

LIMITATIONS

A. The _______ Multi-Sensor Area Navigation System Pilot's Guide, P/N ___________, dated ___________, (or later revision) must be immediately available to flightcrew whenever navigation is predicated on the use of the system.

B. IFR navigation is prohibited unless the pilot verifies each selected waypoint and navaid for accuracy by reference to current approved data.

(If the equipment incorporates a navigation data base or stored flight data, the pilot must verify the currency of this data prior to use.)

C. When using the Multi-Sensor Area Navigation System, additional equipment required for the specific type of operation must be installed and operable.

D. The Multi-Sensor system position must be checked for accuracy prior to use as a means of navigation and under the following conditions:

1. Prior to each compulsory reporting point during IFR operation when not under radar surveillance or control.

2. At or prior to arrival at each en route waypoint during RNAV operation along approved RNAV routes.

3. Prior to requesting off-airway routing, and at hourly intervals thereafter during RNAV operation off approved RNAV routes.

E. The ______ Multi-Sensor Area Navigation System should be updated to satisfy RNAV en route accuracy requirements when a crosscheck with other onboard approved navigation equipment reveals an error greater than 2 nmi.

F. Navigation cannot be predicated on the use of Omega/VLF guidance alone while in terminal areas or during departures from or approaches to airports or into valleys; e.g., between peaks in mountainous terrain or below Minimum Enroute Altitude (MEA).

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MULTI-SENSOR AREA NAVIGATION SYSTEM

G. Following a period of dead reckoning navigation, the system position should be verified and updated, as required, by visually sighting a ground reference point and/or by using other installed navigation equipment, such as VOR, DME, TACAN, or a combination of such equipment.

H. During periods of dead reckoning operation, the _____ Multi-Sensor Area Navigation System should be used with care.

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SECTION III

EMERGENCY PROCEDURES

A. If sensor information is intermittent or lost, utilize remaining operational navigation equipment as required.

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MULTI-SENSOR AREA NAVIGATION SYSTEM

SECTION IV

NORMAL PROCEDURES

A. OPERATION

Normal operating procedures are outlined in the Pilot's Guide, P/N _______, dated ________________, (or later revision).

B. SYSTEM ANNUNCIATORS/DISPLAYS

Describe each remote annunciator or display, such as:

1. Waypoint (WPT)

2. Message (MSG)

3. Dead Reckoning (DR)

4. Crosstrack (X-Track) (Parallel-offset)

5. Equipment Status (signal strength, signal status, signal-to-noise ratio, system failure, etc.)

C. SYSTEM SWITCHES

Describe the function and operation of the various switches used with the system.

D. PILOT'S DISPLAY

Describe the pilot's display (i.e., CDI, HSI, RMI, OBS).

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DATE: __________ Page 6

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MULTI-SENSOR AREA NAVIGATION SYSTEM

E. COPILOT'S DISPLAY

Describe the copilot's display (i.e., CDI, HSI, RMI, OBS).

F. AUTOPILOT OPERATION

Describe the coupling of Multi-Sensor Area Navigation System steering information to the autopilot.

G. FLIGHT DIRECTOR

Describe the coupling of Multi-Sensor Area Navigation System steering information to the flight director.

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MULTI-SENSOR AREA NAVIGATION SYSTEM

SECTION V

ABNORMAL PROCEDURES

No change.

SECTION VI

PERFORMANCE

No Change

FAA APPROVED
DATE: __________

APPENDIX 3. SAMPLE DATA SHEET TO ATTACH TO FAA FORM 337.

ATTACH TO FAA FORM 337
AIRPLANE MAKE:

AIRPLANE MODEL:

AIRPLANE SERIAL NUMBER:

AIRPLANE REGISTRATION NUMBER:

DATE WORK COMPLETED:

_______ Multi-Sensor Area Navigation System, consisting of the following components, was installed per _______ Installation Manual Number __________, Revision ____, dated _____________. The installation conforms to AC 43.13-1A and AC 43.13-2A.

Equipment	Part Number	Serial Number	Software Version
_____ Nav Computer	xxx-xx-xxxx	yyyy-zz	ww
_____ Antenna	xxx-xx-xxxx	yyyy-zz	-
_____ Control/Display	xxx-xx-xxxx	yyyy-zz	ww
etc.			

Proper ground operation of the ________ system was confirmed through completion of the system checkout, Section ____, of the Installation Manual. The system was found to meet or exceed all specifications of this section.

A flight check was made to insure that the accuracy requirements of AC 20-130 were met during flight.( ) YES ( ) NOT APPLICABLE

PLACE MULTI-SENSOR SYSTEM ACCURACY DATA IN AIRCRAFT PERMANENT RECORDS (If applicable)

WAYPOINT:

Latitude/Longitude: _________________________
or
Station Identifier/Frequency: _________________________

Radial: _________________________

Distance: _________________________

Altitude: _________________________

Perpendicular distance to tangent point: _________________________

Distance along track from tangent point: _________________________

MEASURED SYSTEM ERROR:

Along-Track Error ____________________

Crosstrack Error: ____________________

ALLOWABLE SYSTEM ERROR FROM AC 20- 130, PARAGRAPH 8:

Along-Track Error ____________________

Crosstrack Error ____________________

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