U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: AIRWORTHINESS APPROVAL OF NAVIGATION OR FLIGHT MANAGEMENT SYSTEMS INTEGRATING MULTIPLE NAVIGATION SENSORS	Date: 6/14/95 Initiated By: AIR-130	AC No: 20-130A Change:

1. PURPOSE. This advisory circular (AC) establishes an acceptable means, but not the only means, of obtaining airworthiness approval of multi-sensor navigation or flight management systems (hereafter referred to as multi-sensor equipment) integrating data from multiple navigation sensors for use as a navigation system for oceanic and remote, domestic en route, terminal, and non-precision instrument approach [except localizer, localizer directional aid (LDA) and simplified directional facility (SDF)] operations. This document does not address systems incorporating differential GPS capability. Like all advisory material, this AC is not mandatory and does not constitute a requirement. As such, the terms "shall" and "must" used in this AC pertain to an applicant who chooses to follow the method presented. The criteria of AC 90-45A, Approval of Area Navigation Systems for Use in the U.S. National Airspace System, does not apply to certification of equipment described in this AC. This AC supersedes previous GPS installation guidance contained in: FAA Notice 8110.48, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors, and FAA Interim Guidance Memoranda dated February 25, 1991; April 5, 1991; March 20, 1992; July 20, 1992; and September 21, 1993. The appropriate information contained in those documents is incorporated in this AC.

2. CANCELLATION. Advisory Circular 20-130, Airworthiness Approval of Multi-Sensor Navigation Systems for use in the U.S. National Airspace System (NAS) and Alaska, dated September 12, 1988, is canceled.

3 RELATED FEDERAL AVIATION REGULATIONS. 14 CFR parts 21, 23, 25, 27, 29, 43, 91, 121, and 135.

4. RELATED READING MATERIALS.

a. Federal Aviation Administration (FAA) Technical Standard Order (TSO) C115a & b, Area Navigation Equipment Using Multi-Sensor Inputs; C129, Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS); C120, Airborne Area Navigation Equipment Using Omega/VLF Inputs; C94, Omega Receiving Equipment Operating Within the Radio Frequency Range 10.2 to 13.6 Kilohertz; and C60b, Airborne Area Navigation Equipment Using Loran-C Inputs. Copies may be obtained from the Department of

Transportation, FAA, Aircraft Certification Service, Aircraft Engineering Division, AIR-130, 800 Independence Avenue, SW., Washington, DC 20591.

b. RTCA, Inc. Document No. DO-160C, Environmental Conditions and Test Procedures for Airborne Equipment; Document No. DO-164A, Airborne Omega Receiving Equipment; Document No. DO-178B, Software Considerations in Airborne Systems and Equipment Certification; Document No. DO-180A, Minimum Operational Performance Standards for Airborne Area Navigation Equipment Using a Single Collocated VOR/DME Sensor Input; Document No. DO-187, Minimum Operational Performance Standards for Airborne Area Navigation Equipment Using Multi-Sensor Inputs; Document No. DO-190, Minimum Operational Performance Standards for Airborne Area Navigation Equipment Using Omega/VLF Inputs; Document No. DO-194, Minimum Operational Performance Standards for Airborne Area Navigation Equipment Using Loran-C Inputs; Document No. DO-200, Preparation, Verification and Distribution of User-Selectable Navigation Data Bases; Document No. DO-201, User Recommendations for Aeronautical Information Services; and Document No. DO-208, Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Position System (GPS). Copies may be purchased from RTCA, Inc., 1140 Connecticut Avenue, NW., Suite 1020, Washington, DC 20036.

c. Department of Defense, Global Positioning System Standard Positioning Service Signal Specification, November 5, 1993. Copies of this document may be requested from OASD (C3I) / T&TC3, 6000 Defense Pentagon, Washington, DC 20301-6000.

d. Advisory Circular 20-101C, Airworthiness Approval of Omega/VLF Navigation Systems for use in the U.S. National Airspace System (NAS) and Alaska; Advisory Circular 20-121A, Airworthiness Approval of Loran-C Navigation Systems for use in the U.S. National Airspace System (NAS) and Alaska; Advisory Circular 20-129, Airworthiness Approval of Vertical Navigation (VNAV) Systems for use in the U.S. National Airspace System (NAS) and Alaska; Advisory Circular 20-138, Airworthiness Approval of Global Positioning System (GPS) Navigation Equipment for use as a VFR and IFR Supplemental Navigation System; Advisory Circular 23-8A, Flight Test Guide for Certification of Part 23 Airplanes; Advisory Circular 25-4, Inertial Navigation Systems (INS); Advisory Circular 25-7, Flight Test Guide for Certification of Transport Category Airplanes; Advisory Circular 25-11, Transport Category Airplane Electronic Display Systems; Advisory Circular 25-15, Approval of Flight Management Systems in Transport Category Airplanes; Advisory Circular 27-1, Certification of Normal Category Rotorcraft; Advisory Circular 29-2A, Certification of Transport Category Rotorcraft; Advisory Circular 90-79, Recommended Practices and Procedures for the use of Electronic Long-Range Navigation Equipment; Advisory Circular 90-82B, Direct Routes in the Conterminous United States; Advisory Circular 91-49, General Aviation Procedures for Flight in North Atlantic Minimum Navigation Performance Specification Airspace; and Advisory Circular 120-33, Operational Approval of Airborne Long-Range Navigation Systems for Flight Within the North Atlantic Minimum Navigation Performance Specification Airspace. Copies may be obtained from the Department of Transportation, General Services Section, M-443.2, Washington, DC 20590.

e. Defense Mapping Agency (DMA) Technical Report DMA TR 8350.2, Department of Defense World Geodetic System 1984, Its Definition and Relationship With Local Geodetic Systems. Copies of this document may be requested from the Defense Mapping Agency, Systems Center, 8613 Lee Highway, Fairfax, VA 22031-2138.

5. BACKGROUND.

a. System Description. Navigation or flight management systems that determine aircraft position by integrating data from multiple navigation sensors are considered multi-sensor equipment. Aircraft position may be determined by various methods, depending on factors such as availability of sensor inputs, accuracy, signal parameters, location and/or flight phase, signal integrity, etc. Position determination may utilize data from various sensors, such as: distance measurements from two or more distance measuring equipment (DME) ground stations (DME-DME), bearing and distance from very high frequency omnidirectional range (VOR)/DME stations, bearing and distance from tactical air navigation (TACAN) stations, Omega/very low frequency (VLF), Loran-C, inertial navigation system (INS), inertial reference unit (IRU), and the global positioning system (GPS). The various sensor inputs are normally combined to determine a best computed aircraft position, but may be used individually in appropriate circumstances. A more detailed description of the various types of sensors is contained in the related AC and TSO for that type sensor. The coordinate system used is the Cartesian earth-centered earth-fixed coordinates as specified in the Department of Defense World Geodetic System 1984 (WGS-84). Navigational values such as distance and bearing to a waypoint, and ground speed are computed from the aircraft's latitude/longitude and the location of the waypoint. Course guidance is usually provided as a linear deviation from the desired track of a Great Circle course between defined waypoints.

b. System Availability and Reliability. Since multi-sensor equipment determines aircraft position by integrating data from multiple navigation sensor inputs, system availability and reliability is dependent upon the characteristics of the sensors incorporated in the system.

(1) Global Positioning System (GPS).

(i) Although basic GPS position determination capability from the 24 satellite constellation is expected to be available world-wide twenty-four hours a day, the satellite measurement redundancy required to ensure integrity of the GPS position will be neither world-wide nor continuous. With fewer than 24 satellites operating, GPS navigation capability may not be available at particular geographic locations at certain times. At least 21 satellites are expected to be operational with a probability of 98 percent.

(ii) The status of GPS is broadcast as part of the data message transmitted by the GPS satellites. Additionally, system status is planned to be available through the Notice to Airmen (NOTAM) system. GPS status information is also available by means of a telephone data service, (703) 313-5910, or voice, (703) 313-5907, from the U.S. Coast Guard.

(iii) GPS signal integrity monitoring shall be provided by the GPS navigation receiver using receiver autonomous integrity monitoring (RAIM) or an equivalent level of integrity provided by the multi-sensor equipment. This monitoring is necessary because delays up to two hours may occur before an erroneous satellite transmission can be detected and corrected by the satellite control segment. Availability of RAIM detection capability to meet non-precision approach requirements in the United States (with 24 satellites operating, barometric altitude aiding, and a 5 degree mask angle) is expected to exceed 99 percent.

(iv) Only the GPS satellite/ground control system operated by the U.S. Department of Defense is addressed in this AC. Utilization of other satellite navigation systems (i.e., GLONASS) is not covered.

(2) Omega/VLF.

(i) Omega system status is available from the U.S. Naval Observatory, telephone (703) 313-5906. 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). Omega/VLF ground station reliability is high, however reception of the Omega/VLF signals is susceptible to effects of precipitation static and atmospheric noise, especially when using an E-field antenna. Omega/VLF signals are generally usable 24-hours a day anywhere in the world.

(ii) The VLF communications system 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 notice. Information on current VLF system status is not published for the aviation user.

(iii) Omega/VLF navigation sensors, while they may use VLF communications stations to supplement and enhance the Omega system (improve performance, etc.), must be capable of accurate navigation using Omega signals alone.

(3) Loran-C.

(i) Loran-C ground transmitter reliability exceeds 99 percent annually, excluding momentary (less than 60 seconds) ground station outages which occur more frequently (e.g., transmitter switching, adjustments, antenna lightning protection circuitry). These momentary outages can result in loss of Loran-C navigation capability for several minutes, depending upon the particular conditions and design of the Loran-C sensor. Airborne reception of the Loran-C signal (normally using an E-field antenna) is highly susceptible to adverse effects caused by precipitation static and atmospheric noise. Loran-C signal coverage is available throughout the continental United States, southern Alaska, southern and eastern Canada, most of the Gulf of Mexico, the North Atlantic, and various other areas of the world.

(ii) Loran-C navigation predicated on hyperbolic lines of position originating from a single chain may not be suitable for IFR use throughout the entire continental United States and northern Alaska. Equipment utilizing master independent, cross chain, and/or multiple chain receivers has been approved for IFR use in areas where single chain receivers are unacceptable.

(iii) Loran-C system status is available through the NOTAM system and is also available by means of telephone data service (300 or 1200 baud, ASCII) from the U.S. Naval Observatory, telephone (202) 653-1079.

(4) VOR, VOR/DME, VORTAC, TACAN, and Multiple DME.

(i) Ground station availability of these navigation aids exceeds 99 percent annually.

(ii) Coverage of these navigation aids is limited to within line-of-sight of the ground station.

(iii) VOR, VOR/DME, VORTAC, TACAN, and DME system status is available through the NOTAM system.

(5) Inertial Navigation System (INS) and Inertial Reference Unit (IRU).

(i) Inertial navigation/reference systems are self contained and do not rely upon external navigation aids.

(ii) Some inertial systems are not suitable for alignment and/or operation at high north and south latitudes (polar regions).

c. System accuracy. Accuracy of multi-sensor equipment is dependent upon the sensor or combination of sensors in use at a particular time. Various navigation sensor inputs are integrated, considering signal quality, station geometry, integrity, estimated position error, etc. for each sensor and computing a best position based upon all available data. Required system navigational accuracy is specified later in this AC. Individual sensor capabilities are summarized below:

(1) Global Positioning System. The GPS equipment determines its position by precise measurement of the distance from selected satellites in the system and the satellites' known location. The accuracy of GPS position data can be affected by equipment characteristics and various geometric factors. Many of these errors can be reduced or eliminated with sophisticated mathematical modeling, while other sources of error cannot be corrected. Accuracy measurements are affected by satellite geometry, frequently modeled by a geometric

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