U.S. Department of Transportation
**Federal Aviation Administration**

# Advisory Circular

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

**Date:** 8/24/88
**Initiated by:** AIR-120

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**Change:**

1. PURPOSE. This advisory circular establishes an acceptable means, but not the only means, of obtaining airworthiness approval of a Loran-C 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 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 Loran-C navigation equipment.

2. CANCELLATION. Advisory Circular (AC) 20-121, Airworthiness Approval of Airborne Loran-C Systems for Use in the U.S. National Airspace System, dated August 23, 1984, is canceled.

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

4. RELATED READING MATERIALS.

a. Federal Aviation Administration (FAA)/Technical Standard Order (TSO) 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-120), 800 Independence Avenue, S.W., Washington, DC 20591.

b. Radio Technical Commission for Aeronautics (RTCA), Document No. 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-194, Minimum Operational Performance Standards for Airborne Area Navigation Equipment using Loran-C Inputs. Copies may be purchased from RTCA Secretariat, One McPherson Square, Suite 500, 1425 K Street, N.W., Washington, DC 20005.

c. Advisory Circular 90-82, Random Area Navigation Routes. Copies may be obtained from the Department of Transportation, Utilization and Storage Section, M-443.2, Washington, D.C. 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 Loran-C 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 Loran-C area navigation system in a transport category rotorcraft. If necessary, AC 29-2 will address those items peculiar to rotorcraft installations. Copies may be obtained from the Department of Transportation, Utilization and Storage Section M-443.2, Washington, D.C. 20590.

5. BACKGROUND.

a. System Description. Loran-C is a radio navigation system which uses time synchronized pulsed signals from ground transmitting stations spaced several hundred miles apart. The stations are configured in chains of three to five stations which transmit with the same pulse group repetition interval (GRI). Within each chain, one station is designated as master and the remainder as secondaries. The master has unique pulse and phase transmission characteristics to distinguish it from the secondaries. Loran-C position is derived by measuring the difference in arrival time of pulses from three or more ground stations. The U.S. Coast Guard (USCG) presently uses a homogeneous spheroid for the earth model for the Loran-C system based on the World Geodetic System, 1972 Datum (may be updated to 1984 Datum), and the Defense Mapping Agency Sea Water Propagation Model for the propagation model. Navigational 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 succesive waypoints.

b. System Availability and Reliability.

(1) 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 have been approved for IFR use in areas where single chain receivers are unacceptable.

(2) Loran-C system status is available through the Notice to Airmen (NOTAM) system.

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

(3) Expansion of Loran-C coverage and improvements in signal integrity are presently being jointly accomplished by the FAA and USCG.

c. Loran-C Position Errors. The accuracy of Loran-C navigation can be degraded by various factors. Errors are caused by the slower signal propagation over land and fresh water than over sea water. These errors appear to be quite constant over distances of up to several miles. The effect of these errors is a shift or bias in the computed latitude/longitude in the local area. Use of another triad in the same area may produce a different bias value. Area calibration procedures may reduce the effect of these bias errors. Errors can also be caused by weather fronts, abrupt changes in terrain, noise, and geometric considerations, among others. These effects can be minimized by incorporation of propagation models and other correction factors which substantially reduce these errors automatically.

d. General Operational Limitations.

(1) En Route and Terminal National Airspace System (NAS) Use. A Loran-C 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., Very High Frequency Omni Range (VOR), Distance Measuring Equipment (DME), Tactical Air Navigation (TACAN), Automatic Direction Finder (ADF)) 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.

(2) Approach Use in the NAS. A Loran-C system may be approved for instrument approach operations within the conterminous United States and Alaska provided the installed system meets the minimum performance requirements of TSO-C60b. Operator entry of calibration or correction factors shown on a charted instrument approach procedure may be used in satisfying approach accuracy requirements.

(3) IFR Navigation Equipment. Aircraft employing Loran-C for IFR navigation should also be equipped with an approved alternate means of navigation.

(4) Loran-C Operational Areas. Operational use of the Loran-C system may be limited to specified Loran-C Operational Areas (LOA's) because of system characteristics and other factors affecting system performance. Loran-C operation should be limited to those geographic areas where the equipment has been demonstrated to meet the performance specifications of this advisory circular.

6. 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. Area Calibration. Area calibration is a procedure where time measurement correction factors are input into the Loran-C system to reduce the effect of propagation anomalies.

c. Baseline. A line between a Loran-C master station and one of its secondary stations or between two secondary stations.

d. Baseline Extension. The extension of the baseline beyond the master or secondary station. Navigation in this region may be inaccurate due to geometrical considerations resulting in ambiguous position solutions.

e. Blink. A method of indicating non-standard operation of a Loran-C station be switching off and on the ninth pulse of an affected master station or the first two pulses of an affected secondary station. Blink is used to denote that a station is operating outside of specified tolerances.

f. Cycle Slip. Erroneous use of an incorrect cycle of the 100 kHz carrier of the Loran-C signal for time measurements. Normally the third cycle of a given pulse is used for time measurement. Each cycle slip will result in a 10 microsecond error in time measurement and a corresponding error in navigation.

g. 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 Advisory Circular 90-82, Random Area Navigation Routes.

h. Envelope-to-Cycle Discrepancy (ECD). The discrepancy between the desired and actual zero phase crossing at the end of the third cycle of the Loran-C pulse. U.S. Coast Guard specifications for the Loran-C transmitted signal provide a further definition of ECD.

i. Geometric Dilution of Precision (GDOP). A factor used to express navigational error at a position fix caused by divergence of the hyperbolic lines of position as the receiver's (aircraft's) distance from the baseline increases.

j. Group Repetition Interval (GRI). The time interval (measured in tens of microseconds) between one group of pulses and the next from any transmitter within a Loran-C chain. All stations in a specific chain use the same GRI.

k. Group Repetition Rate (GRR). The reciprocal of the GRI (usually measured in groups per second).

l. Line of Position (LOP). A hyperbolically curved line defined by successive but constant time difference (TD) measurements using the signals from two Loran-C transmitters. Two crossing LOP's define a receiver's location, thus at least three Loran-C stations must be used to establish a position fix.

m. Master Dependent Mode. A Loran-C operating mode where all time difference measurements are executed with reference to the master's pulses.

n. Master Independent Mode. An operating mode used in some receiver designs in which a secondary station signal may be substituted for the master station signal.

o. 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 the Loran-C receiver can no longer detect the transmitted signal.

p. Skywave. Loran-C signal energy traveling such that it is reflected by the ionosphere. Skywaves travel farther than the ground wave to reach a given point and can interfere with ground wave reception at some locations.

q. Time Difference (TD). The elapsed time, in microseconds, measured at the receiver (aircraft), between the arrival of a set of pulses from one Loran-C station's signal to the arrival of a set of pulses from another station's signal.

r. Triad. The collective name given to the three stations from a Loran-C chain from which navigational information is being derived.

s. 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.

7. AIRWORTHINESS CONSIDERATIONS. Loran-C navigation systems have been certificated for VFR and IFR use as an area navigation system for en route and terminal navigation in the NAS. This paragraph establishes acceptable criteria for Loran-C systems.

a. Loran-C Installations Used for Operations Under Visual Flight Rules (VFR) Only. Operators wishing to use Loran-C 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 Loran-C 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 Loran-C 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 Loran-C 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 Loran-C 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 Loran-C Controls and displays are Installed with a placard(s) which states "Loran-C Not Approved for IFR."

(5) The Loran-C 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. Loran-C Installations Used as an Area Navigation System Under Instrument Flight Rules (IFR). The standards for navigation within the NAS are more stringent than the requirements for long-range, over-water navigation. Loran-C equipment produced under TSO-C60a is not necessarily appropriate for en route area navigation under instrument flight rules since this technical standard order was originally written for long-range, over-water navigation. Minimum performance standards for Loran-C equipment to be used in the NAS are specified in TSO-C60b. Equipment previously certified using TSO-C60a and AC 20-121/AC 90-45A may continue to be approved for en route and terminal operations provided the appropriate performance standards are satisfied. Equipment approved for non-precision approaches must have TSO-C60b approval and meet specified minimum performance standards. Criteria for area navigation (RNAV) systems based on Loran-C navigation are amplified in the following paragraphs. The initial certification of a Loran-C 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 Loran-C system in other aircraft may require additional engineering evaluation, depending upon the degree of integration of the Loran-C system with other aircraft systems. An engineering evaluation will be necessary to change or increase approved operating areas. Loran-C systems for use under instrument flight rules should provide the following:

(1) Flightcrew Inputs of:

(i) Aircraft present position in terms of latitude and longitude at least to 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 to at least 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) Chain (master and secondary) and GRI designation if the system requires manual designation.

(vii) A means for manual update of system position by the pilot to permit insertion of a known present position.

(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 nautical mile (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 1.0 nmi.

(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.

(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 | ≥5.0 | * ≥1.25 |
| Readability | ≤1.0 | ≤0.25 |
| Minimum Discernable Movement | ≤0.1 | ≤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.

(vii) 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.

(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 Loran-C stations currently used in the navigation calculations as well as the status of all 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 7b(2)(f) 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 9 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) When Within an Acceptable LOA, the system shall be able to properly acquire and track signals and provide navigation to the accuracies specified in paragraph 9 under the conditions and within the time limits specified in TSO-C60b.

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

(6) The Equipment Should Have The Capability to meet the criteria outlined in paragraph 7b(1) through 7b(5) throughout the range of environmental conditions which will be encountered in actual service. Exposure of the equipment to the environmental test conditions of TSO-C60b may be used to demonstrate this capability. Environmental testing to obtain a TSO-C60a authorization may be used provided that the test results also demonstrate compliance with the criteria of paragraph 7b(1) through 7b(6).

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

(8) The Equipment Should Not Exceed the Error Values specified in paragraph 9 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 lesser value specified by the equipment manufacturer.

(9) 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 7b(2)(f). For Loran-C 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.

(10) 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 7b(9).

c. Software Changes. The provisions of this paragraph apply to Loran-C 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 Loran-C equipment described in paragraph 7b (for Loran-C used for IFR operations) should be verified and validated to at least the level 2 requirements as defined by RTCA/DO-178A, "Software Considerations in Airborne Systems and Equipment Certification." 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 Loran-C 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 Loran-C 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 Loran-C equipment has a software configuration mangement 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.

8. EQUIPMENT INSTALLATION CONSIDERATIONS FOR USE UNDER IFR.

a. Location of the Loran-C Display. 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 Loran-C navigation system should not degrade the normal operation of other required equipment or create a flight hazard. Normal operation of the Loran-C installation should not adversely affect the performance of other aircraft equipment.

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

d. Electromagnetic Interference. The Loran-C 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, the aircraft should be protected by placing the antenna in a suitable location, by acceptable bonding techniques and installation of static dischargers. These protective devices should be specified as part of the approved

design data for the Loran-C installation. The capability to provide satisfactory P-static protection for the Loran-C 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 Loran-C 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 Loran-C 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 Loran-C system 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 Loran-C system can be shown to operate satisfactorily when the antenna 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 9 within 15 seconds following aircraft maneuvering or changes in attitude encountered in normal operations.

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 Loran-C system for IFR use involves extensive testing to demonstrate system performance, operational areas, environmental qualifications, etc., as described in paragraph 7b(6). 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 Loran-C signals during normal flight maneuvers, satisfactory clearance of electromagnetic interference (EMI), and functional check of the Loran-C equipment.

j. Manufactuer's Instructions. Loran-C equipment should be installed in accordance with instructions and limitations provided by the manufacturer of the equipment.

k. Approach Mode Limitation. Loran-C equipment capable of selecting an "approach" mode on the control panel shall be placarded "Approach Mode Not Approved for IFR," unless the equipment is approved for conduct of Loran-C nonprecision instrument approaches.

9. SYSTEM ACCURACY.

a. En Route IFR Operation Along Random (Off Airways) RNAV Routes with Radar Coverage. The error of the airborne Loran-C 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 Loran-C equipment should be less than ±2.8 nmi of crosstrack 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 Loran-C 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 Loran-C equipment should be less than ±0.3 nmi of crosstrack error on a 95 percent probability basis and ±0.3 nmi 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 Loran-C 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 | ±0.6 nmi |

10. 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 Loran-C equipment for FAA airworthiness installation approval and certification for an IFR navigation system. Any new models of Loran-C 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 factor 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 Loran-C 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 Loran-C 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 Loran-C installation will not cause overloading of the aircraft's electrical generating capacity.

(vi) Evaluation of the antenna installation. A critical aspect of any Loran-C installation is the installation of the antenna. The Loran-C signal is quite weak, typically only one-third the value of the background noise. Electrical noise in the vicinity of the antenna can render the Loran-C equipment useless.

(A) 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.

NOTE: 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 Loran-C installation and must be maintained for proper system operations.

(B) 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.

NOTE: 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 Loran-C equipment and record signal-to-noise values (or quality factors) for all receivable stations. 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 Loran-C equipment.

(B) Examination of the interface (function) of other equipment connected to the Loran-C equipment.

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

(D) Evaluation of steering response while autopilot is coupled to the Loran-C equipment during a variety of different track changes.

(E) Evaluation of displayed Loran-C navigation parameters on interfaced flight deck instruments such as HSI, CDI, etc.

(F) Assessment of all switching and transfer functions pertaining to the Loran-C 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 Loran-C installation and other onboard equipment, or vice versa.

(H) Evaluation of the acessibility of all controls pertaining to the Loran-C installation.

(I) Evaluation of the visibility of the displays and annunciators pertaining to the Loran-C installation during day and night lighting conditions. No distracting cockpit glare or refections may be introduced.

(J) Analysis of crew workload when operating the Loran-C equipment.

(ii) Determination of Navigation Error Flight Test. The initial certification of each Loran-C system to be used for IFR operations should be based on a demonstration of system performance by recording the Loran-C equipment position and comparing it to the actual position of at least 100 locations distributed throughout the Loran-C 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 9 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 the Loran-C signal 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. For receivers that track only one chain at a time, at least 50 percent of the accuracy measurements should be accomplished at or near the extremes of each defined LOA. For master independent, cross chain, and multi-chain receivers, at least 50 percent of the accuracy measurements should be accomplished at or near the extremes of the combined chain coverage area. At these points, the system should also demonstrate its ability to acquire the Loran-C signal after power interruption.

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 Loran-C 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. The applicant or installing agency requesting a follow-on Loran-C 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 10a(2).

(3) Conduct flight evaluations similar to the flight tests outlined in paragraph 10a(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 Loran-C 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 Loran-C 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.) The receiver should demonstrate the ability to properly acquire the Loran-C signal under varying conditions, including at least five acquisitions in flight and five on the ground. Acquisition demonstrations should encompass a variety of chains (for single chain receivers) and, if possible, poor signal quality areas. If possible, this flight should include areas of poor coverage to observe proper operation of appropriate annunciations. 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 9 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.

11. OPERATIONAL CONSIDERATIONS.

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

b. Loran-C Operational Area. Operators and their flightcrews should consult the approved flight manual supplement for their aircraft to determine approved operational areas that apply to their aircraft. Flightcrews must be aware that operational areas may be different for different Loran-C systems, 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.

M. C. Beard
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 nearest 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 10. 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 Loran-C 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 9), or conducts the necessary tests.

(4) Makes an aircraft available (with the Loran-C 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 a technical standard order authorization.

(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 revision or 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 performance criteria in paragraph 9 by reference to the original STC have been satisfied, 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 performance requirements of paragraph 9 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 technical standard order 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 Loran-C system and any interfaced equipment.

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

d. The applicant makes an aircraft available (with the Loran-C 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 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 Loran-C installation without the need for engineering assistance. However, if engineering assistance is needed, then the inspector should request it early in the program.

e. Field approvals of Loran-C installations for IFR should be limited to follow-on installations where the original approval was through the TC or STC process and where the system installation is either of the stand-alone kind or where the interface 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 Loran-C deviation and flag signals for the comparable outputs of one VOR receiver. Field approvals without engineering assistance should not be made when:

(1) The Loran-C equipment transfers or accepts data from other navigation systems or computers such as inertial, Omega, or flight management systems;

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

(3) The Loran-C equipment incorporates a software configuration that has not been FAA approved.

3. APPROVAL OF INSTALLATION FOR VFR OPERATIONS. Approval of Loran-C 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 then be approved for return to service 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 AC 43.13-1A, Acceptable Methods, Techniques and Practices - Aircraft Inspection 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 Loran-C equipment is not a source of objectional electromagnetic interference (EMI), is functioning properly and safely, and operates in accordan with the manufacturer's specifications.

c. Does not involve complex switching for integration with other aircraft systems; e.g., flight directors, electronic flight instrument system (EFIS) displays, etc. The Loran-C 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 if the Loran-C 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 is in clear view of the pilot which indicates "Loran-C Not Approved For IFR."

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