U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: AIRWORTHINESS APPROVAL OF AIRBORNE LORAN-C SYSTEMS FOR USE IN THE U.S. NATIONAL AIRSPACE SYSTEM

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1. PURPOSE. This advisory circular establishes an acceptable means, but not the only means, of obtaining airworthiness approval of airborne Loran-C navigation systems for use under visual flight rules (VFR), and instrument flight rules (IFR) as an area navigation (RNAV) system within the conterminous United States, Alaska, and surrounding U.S. waters.

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

3. RELATED READING MATERIAL.

a. Advisory Circular 90-45A, Approval of Area Navigation Systems for Use in the U.S. National Airspace System, and Advisory Circular 90-82, Random Area Navigation Routes. Copies may be obtained from the U.S. Department of Transportation, Subsequent Distribution Unit (M-494.3), Washington, D.C. 20590.

b. Radio Technical Commission for Aeronautics (RTCA), Document No. RTCA/DO-159, "Minimum Performance Standards - Airborne Loran-A and Loran-C Receiving Equipment," Document No. RTCA/DO-160A, "Environmental Conditions and Test Procedures for Airborne Equipment," and Document No. RTCA/DO-178, "Software Considerations in Airborne Systems and Equipment Certification." Copies may be purchased from the RTCA Secretariat, One McPherson Square, Suite 500, 1425 K Street, N.W., Washington, D.C. 20005.

c. Technical Standard Order (TSO) C-60a, Airborne Loran-A and Loran-C Receiving Equipment Operating Within the Radio Frequency Ranges of 1800-2000 Kilohertz and 90-110 Kilohertz Respectively. Copies may be obtained from the Federal Aviation Administration, Office of Airworthiness, Aircraft Engineering Division (AWS-100), 800 Independence Avenue, S.W., Washington, D.C. 20591.

4. 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 uses a homogeneous spheroid for the earth model for the Loran-C system based on the World Geodetic System, 1972 Datum, and the Defense Mapping Agency Sea Water Propagation Model for the propagation model. Navigational values in terms of 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 location of successive waypoints.

b. System Availability and Reliability. Hyperbolic lines of position originating from a single chain are not presently available for IFR use in the central United States and much of northern Alaska. Ground transmitter reliability exceeds 99% annually. Transmitter outages are not included in the Notice to Airmen (NOTAM) system at this time. Expansion of Loran-C coverage (reference Appendix 3), improvements in signal integrity, and a Loran-C NOTAM system are currently under study by FAA and USCG.

c. Loran-C Errors. The accuracy of Loran-C can be degraded by errors caused by the slower signal propagation over land and fresh water than over seawater. These errors appear to be quite constant over distances of up to several miles. The effects of these errors are a shift or bias in the computed latitude/longitude in the local area. The 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. Additionally, some receivers may incorporate propagation models which substantially reduce or eliminate these errors automatically.

d. General Operational Limitations. Due to system availability and integrity, the effect of bias errors and other factors including signal reacquisition time, and possible interference from outside sources, operational limitations must be imposed on the use of Loran-C at this time. These general limitations are as follows:

(1) Loran-C Operational Areas. The airworthiness approval for Loran-C may be limited to a Loran-C Operational Area (LOA) because of system availability and other factors affecting system performance. The applicant should define the LOA's of each system.

(2) Offshore Helicopter Use. Use for offshore helicopter en route navigation to oil rigs is considered feasible with manual area calibration correction procedures or automatic bias correction if needed.

(3) Transmitter Monitoring. Currently, ground station transmissions may be out of tolerance for as long as 60 seconds before the station is shut down or blink is initiated.

(4) En Route and Terminal National Airspace System (NAS) Use. En route and terminal IFR use on the Very High Frequency Omni-Directional Range (VOR) and the Distance Measuring Equipment (DME) Federal Airway System is considered acceptable within the LOA provided en route accuracies can be met without the need for area calibration by the operator. However, the manufacturer may incorporate bias correction as part of the system design if these corrections are applied automatically. The time necessary for chain switching should not exceed 7.5 minutes. If chain switching results in a disruption to the Loran-C navigation information exceeding 2 minutes, instructions should be provided to the flightcrew to use alternate means of navigation during chain switching. Instructions should also be provided to the flightcrew to plan the flight to preclude the need for chain switching in the terminal area. Means should be provided to inhibit automatic switching when operating in the terminal area, unless signal acquisition and tracking can be accomplished without a detectable interruption of navigation information.

(5) Nonprecision Approach Use in the NAS. The Loran-C is not approved for approach at this time.

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

5. DEFINITIONS.

a. Area Calibration. Area calibration is a manual mode of operation requiring pilot input to the Loran-C unit, intended to reduce the effect of propagation anomalies. Application of correction values to the Loran-C system is a function of receiver design.

b. Automatic Station Switching. Automatic station switching is a design feature of some navigation computers allowing for automatic station selection based on the most advantageous arrangement of stations in a given operating area.

c. Baseline. Points on the earth's surface that are on a line between the 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 beyond the secondary station. Navigation in this region may be inaccurate due to geometrical considerations.

e. Bias Correction. Bias correction is an automatic process performed by the Loran-C receiver which obtains data from a preprogrammed propagation model and applies correction values to the Loran-C system.

f. Bias Error. An error in position which is constant over an area several miles in extent. Bias errors are caused by slower signal propagation over land areas than over seawater and by seasonal changes in propagation. Bias errors are not constant through the year, and may be reduced by receiver designs that employ improved automatic bias corrections.

g. Blink. A switching of specified pulses from a Loran-C station in a repetitive on-and-off pattern. Blink is used to denote that a station's timing is outside of specified tolerance.

h. Chain. Three or more stations which transmit in sequence and with the same group repetition.

i. Cycle Slip. Erroneous use of a cycle of the 100 Khz carrier of Loran-C pulses for time measurements other than the desired cycle; each "cycle slip" will result in a 10-microsecond error in time measurement and a corresponding error in navigation.

j. 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 waypoints defined as part of these charted routes, or along great circle routes as described in Advisory Circular 90-82.

k. Geometric Dilution of Precision (GDOP). A factor used to express all geometric causes of navigational error at a position fix isolated from errors associated with measurement uncertainties.

l. 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.

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

n. Line of Position (LOP). For any given time difference computed for any two given Loran-C stations, the solution plots a locus of points forming a hyperbolic line called an LOP. The crossing point of two LOP's determine the position of the receiver or "fix".

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

p. Master Independent Mode. An operating mode used in some receiver designs in which a secondary's signal may be substituted for the master when the master signal is unavailable. Some receiver designs may allow for secondary/secondary tracking whether or not the master signal is available. Some systems may provide range/range configuration rather than a hyperbolic solution. Each operating mode of a Loran-C system used for IFR navigation must be shown to meet the minimum accuracy standards of paragraph 8.

q. Multiple Chain Receivers. Some receivers incorporate features which enable them to track stations from several chains simultaneously, thereby eliminating chain/station switch times and eliminating the resulting periodic loss of navigation data.

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

s. Time Difference (TD). The real time value computed by the Loran-C receiver, in microseconds, of the difference in time in receiving pulse's from two different stations.

t. Precipitation Static (P-Static). P-static is electromagnetic noise generated by the dissipation of an electrical charge on an aircraft into the atmosphere. The aircraft becomes charged by flight through charged 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.

u. Triad. The collective name given to the master and two secondaries or three secondaries from which navigational information is being derived.

6. AIRWORTHINESS CONSIDERATIONS. Currently, Loran-C has been certificated for VFR and IFR use as an area navigation system for en route and terminal area navigation in the National Airspace System (NAS). This paragraph establishes acceptable criteria for Loran-C systems.

a. Loran-C Installations Used for Operations Under VFR. Operators wishing to use Loran-C for operations under VFR may obtain approval of the installation by Type Certification (TC), Supplemental Type Certification (STC), data field approved by the Federal Aviation Administration (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, 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) and 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) or equipment which is normally used to operate the aircraft.

(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 Loran has a CDI 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). Loran-C equipment produced under TSO-C60a is not necessarily appropriate for en route or terminal area navigation under instrument flight rules because this technical standard order was written for a long-range, over-water system. The standards for navigation within the National Airspace System are more stringent than the requirements for long-range, over-water navigation. When employed in the National Airspace System, it is appropriate to consider a Loran-C navigation system as an area navigation (RNAV) system. Criteria for RNAV systems are contained in Advisory Circular 90-45A and are amplified in the following subparagraphs for RNAV systems based on Loran-C navigation. These criteria are applicable to systems used for flight along published airways. Some standards are relaxed, as indicated, if the system is to be used only for en route navigation on random (off airways) RNAV routes. The initial certification of a Loran-C system requires an engineering evaluation because of the need to verify accuracy, failure indications, and environmental qualification. Subsequent installations of a Loran-C system in other aircraft may also require additional engineering evaluation depending on the degree of integration of the Loran-C system with the aircraft controls and displays. Engineering evaluation will be necesssary to change or increase the LOA's. Loran-C systems for use under instrument flight rules should provide the following:

(1) Flightcrew Inputs of:

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

(b) At least three waypoint positions in terms of latitude and longitude to the nearest 0.1 minute; as many as ten waypoints may be needed for some terminal area operations.

(c) Chain designation by entry of an appropriate means of identification, if the system requires manual chain designation.

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

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

(2) The system displays should give no operationally misleading information and should provide:

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

(b) Waypoint position designation in terms of latitude and longitude to the nearest 0.1 minute and 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 the nearest degree of bearing and to the nearest 0.1 nautical mile for systems used for terminal area operations. Systems limited to en route operations need only designate distance to the nearest whole nautical mile.

NOTE: Information should be provided to the flightcrew 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).

(c) A display of active waypoint 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.

(d) A display of the desired track in terms of the appropriate magnetic course to 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.

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

(f) A continuous analog display of cross-track deviation with a dynamic range of at least $\pm$ 5 nm and a resolution of 1.0 nm.

(g) A display of cross-track deviation to the nearest 0.1 nm up to 9.9 nm and 1.0 nm beyond, with a range of at least $\pm$ 20 nm. This may be a digital display and need not be part of the course deviation indicator.

(h) A display of the distance and magnetic bearing between waypoints to the nearest 1.0 nm and 1.0 degree.

(i) A display of the group repetition interval (GRI) of the chain being used for navigation, if the system requires manual chain designation.

(3) Caution indication(s) for the system should be located on or near the indicator specified in paragraph 6b(2)(f) and should provide a readily discernible caution indication(s) to the pilot(s) for any of the following:

(a) Loss of Loran-C signals necessary for accurate navigation to the criteria specified in paragraph 8 within 30 seconds of signal loss.

(b) Detection of the blink of a station used for Loran-C navigation within 30 seconds of station blink.

(c) Navigational accuracy degraded below that specified in paragraph 8 due to conditions such as unsatisfactory signal-to-noise ratio, station geometry, or possible cycle slip.

(d) Detection of any probable failure of major system functions of the airborne equipment.

(4) Automatic station switching within the acceptable Loran-C operational area of each chain which the system is certificated to use. Automatic station switching shall not cause a disruption of navigation information for more than five seconds.

(5) When within an acceptable Loran-C operational area, the system shall be capable of determining position to the accuracies specified in paragraph 8 within 7.5 minutes after selection of a new chain when at the limits of the Loran-C operational area defined by the manufacturer and upon application of electrical power with no particular time limit for signal acquisition.

(6) Loran-C systems used for terminal area navigation should provide a means to inhibit automatic chain and triad switching if such switching causes an appreciable disruption of navigation information.

(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 environmental test conditions of RTCA/DO-160A may be used to demonstrate this capability. The environmental testing of the Loran-C system to obtain a TSO-C60a authorization may be used, provided that the test results demonstrate compliance with the criteria of paragraph 6b(1) through 6b(6), in addition to the requirements of TSO-C60a.

(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 useable 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. Accurate position information as specified in paragraph 8 should be displayed at least when flying the inbound course to the holding fix when entering or flying the holding pattern.

(10) A means to alert the flightcrew prior to arrival at a waypoint to permit turn anticipation in accordance with the approximate formula of 1.0 nm for each 100 knots of groundspeed should be located on or near the indicator specified in paragraph 6b(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. Instructions for accomplishing turns should be provided to the flightcrew for installations where the flight director or autopilot do not provide such turn anticipation when coupled to the Loran-C system.

(11) If a capability for parallel offset tracks is provided, track selection should be in increments of 1.0 nm left or right up to an offset of 20 nm. Means should be provided to 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 bi-sector of the parent track. These functions should operate as described in paragraph 6b(10).

c. Software Changes. The provisions of this paragraph apply to Loran-C equipment which utilize 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 navigation and monitoring functions of Loran-C equipment described in paragraph 6b, for Loran-C used for IFR operations, are considered to be essential functions as defined by RTCA/DO-178, "Software Considerations in Airborne Systems and Equipment Certification." Any changes to software which provides essential functions are considered to be major changes to the equipment. All changes to software that does not affect flight essential functions may be approved without FAA participation providing the manufacturer of the Loran-C equipment has a verification and validation plan approved by the FAA. This is necessary because even small changes to software have the potential for disrupting computer operation. Software used for Loran-C equipment limited to VFR use or partitioned from software which provides essential functions in IFR systems are considered to be minor and do not need to be approved by the FAA. However, all software changes must be identified on the outside of the associated line replaceable unit in accordance with the criteria of RTCA/DO-178. If the equipment displays a software identifier to the flightcrew, the airplane or rotorcraft flight manual (or appropriate placard) should indicate the approved identifier.

7. 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, should be located where it is clearly visible to the pilot 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 Loran-C 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 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 Vne, Vmo, or Mmo through known P-static conditions such as a cloud of ice crystals. Loss of signal for periods not exceeding two minutes is acceptable when encountering heavy P-static 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 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 type 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.

(2) Anti-Ice Protection. If the aircraft in which the Loran-C 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 the Loran-C system is not to be used for navigation during flight into known icing conditions, then anti-ice protection is not required.

f. Dynamic Responses. The system operation should not be adversely affected by aircraft maneuvering or changes in attitude encountered in normal operations. Within five seconds after any normal maneuver, the system shall be capable of providing the accuracy specified in paragraph 8.

g. 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 useable by, the flightcrew and be visible under all expected lighting conditions.

h. System Tests. The initial approval of a Loran-C system for IFR use involves extensive testing to demonstrate accuracy and environmental qualifications 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 Loran-C signals during normal flight maneuvers, satisfactory clearance of electromagnetic interference (EMI), and a functional check of the Loran-C equipment.

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

j. 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".

8. 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 nm of cross-track error on a 95% probability basis and ± 3.8 nm of along-track error on a 95% probability basis without the need for area calibration entered by the flightcrew. When operating within the Loran-C operating areas shown in Appendix 3 of this advisory circular, Loran-C equipment designed for aircraft use will normally exhibit smaller errors than are listed in this advisory circular. Therefore, expanded utilization of Loran-C may be possible with this minimum level of accuracy in alternate operating modes such as master independent operation or operation using the stations of more than one chain. The operating area to be used should be proposed by the applicant and verified by test.

b. En route IFR Operation and Terminal Area Operation on Airways and on Standard Terminal Arrival and Departure Routes in the NAS. The error of the airborne Loran-C equipment should be less than ± 2.8 nm of cross-track error on a 95% probability basis and ± 2.8 nm of along-track error on a 95% probability basis for approval of en route IFR operations on airways. The error should be less than ± 1.7 nm of cross-track error on a 95% probability basis and ± 1.7 nm along-track error on a 95% probability basis for IFR terminal area operations on standard terminal arrivals (STAR's), or standard instrument departures (SID's), and transitions. These accuracies must be achieved without the need for the flightcrew to enter area calibration data.

c. Flight Technical (Pilotage) Errors. With satisfactory displays of cross-track 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 nm
Terminal Area	± 1.0 nm

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 cross-track accuracy shown below should be maintained.

If an installation results in larger flight technical errors, the total cross-track 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 Cross-Track Error
Random RNAV Routes	± 4.0 nm
En route, on Airways	± 3.0 nm
Terminal Areas	± 2.0 nm

NOTE: These values supersede those shown in Advisory Circular 90-45A for similar conditions due to new research data and changes in the airway system since its publication.

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 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:

(a) 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-178 where system performs essential functions.

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

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

(d) Analysis of failure modes.

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

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

(g) Review of installation and maintenance manuals.

(h) 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:

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

(b) Examination of a cockpit layout of the installed equipment with emphasis on equipment controls, displays, and annunciators.

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

(d) 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.

(e) 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.

(f) Evaluation of the antenna installation. A critical aspect of any Loran-C installation is the installation of the antenna. When not in the vicinity of a transmitter 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.

1 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. The P-static protection is a required part of the Loran-C installation and must be maintained for proper system operation.

2 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. The 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 for all receivable stations. Repeat this process of recording signal-to-noise values 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.

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

(a) Functional Flight Tests Consist of:

1 Evaluation of all operating modes of the Loran-C equipment.

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

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

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

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

6 Assessment of all switching and transfer functions pertaining to the Loran-C installation including high-power electrical loads and electrical bus switching.

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

8 Evaluation of the accessibility of all controls pertaining to the Loran-C installation.

9 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 reflections may be introduced.

10 Analysis of crew workload when operating the Loran-C equipment.

(b) 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 accuracy by recording the Loran-C equipment position and comparing it to the actual position of at least 100 locations distributed within the Loran-C operational area of each chain for which the manufacturer wants approval. The limits of each operational area are to be proposed by the applicant, but must be clearly defined in a manner easily understood by the flightcrew. Areas much larger than those shown in Appendix 3 may not be able to provide sufficient accuracy for operations in terminal areas or on airways. These measurements should be recorded in flight by a VORTAC overflight at low altitude (less than 3,000' AGL), comparison with a good dual DME fix, or a visual sighting of a known ground reference point. The data should demonstrate that the appropriate accuracy criteria of paragraph 8

are met on a 95% probability basis. Flights beyond the desired Loran-C operational area 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 should be conducted. Normal flight manuevers should not cause loss of the Loran-C signal and the system dynamic response should be confirmed. Flight technical errors and errors resulting from use of the autopilot and flight director should be determined. Fifty of the accuracy measurements should be located at or near the extremes of each defined LOA. 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 Type Certificate (TC) or a Supplemental Type Certificate (STC), as a basis for installation approval. This data approval 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:

(a) Obtain a sample airplane flight manual (AFM) or rotorcraft flight manual (RFM) supplement.

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

(c) 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)(a).

(4) Verify that an 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) Conduct a few VORTAC overflights, not for the purpose of navigation error validation, but to assure proper system function. The first-time approval has determined equipment accuracy. The purpose of this test flight is 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 where the excessive error occurred. If such an error persists, approval of the installation should be withheld.

10. OPERATIONAL CONSIDERATIONS.

a. Loran-C Operational Area. Operators and their flightcrews should consult the approved flight manual supplement for their aircraft to determine the Loran-C operational area which may apply. Inquiries pertaining to outages and scheduled maintenance should be directed to appropriate U.S. Coast Guard authorities. Flightcrews should be aware that the Loran-C operational areas may be different for different Loran-C systems, and the appropriate operating area for a particular system can only be determined by reference to the airplane flight manual or other FAA-approved documents.

b. 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 U.S., this requirement may be met with the installation of a VOR receiver in addition to the Loran-C system approved for IFR operation when operating within the Loran-C operational area.

c. Ambiguous Solution. In some locations, limited triad receivers may compute Loran-C lines of position which may cross at two places creating the possibility of an ambiguous navigational solution. Multiple chain Loran-C receivers are generally immune from this problem if tracking more than three stations. Although the alternate solution is usually several hundred miles from the actual aircraft position, this distance may be only several miles in certain geometric situations. Flightcrews should be made aware of this problem and use manufacturer's recommended procedures which should be a part of the airplane flight manual supplement or rotorcraft flight manual supplement to correct this problem.

M. C. Beard
Director of Airworthiness

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 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 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 8), 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 conducting the required flight tests.

b. Data Submitted by the STC Applicant. The following kinds of data should be submitted for FAA airworthiness evaluation:

(1) 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 unless equipment has been manufactured in accordance with a technical standard order.

(2) Fault analysis covering installation.

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

(4) Structural substantiation as necessary.

(5) Installation wiring diagrams.

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

(7) Evidence of previously approved data.

(8) Electrical load analysis.

c. The equipment manufacturer can certify (to the applicant and FAA) that the accuracy criteria in paragraph 8 by reference to the original STC are satisfied, a TSO has been obtained, or 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 schematics, 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 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 conducting 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: In most instances, the FAA inspector will evaluate and sign the airplane flight manual supplement or rotorcraft flight manual supplement 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 which are either stand alone or which have simple interfaces with autopilot, flight director, and aircraft instruments. 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 INS, Omega/VLF, or flight management systems;

(2) The Loran-C equipment outputs a "roll steering command" instead of left/right deviation to the autopilot or flight director; and

(3) The aircraft has numerous sources of navigation information installed wth a complex-switching system.

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 can then be approved for return to service signed by one of the entities noted in FAR 43; i.e., repair station, manufacturer, inspection authorization, etc., provided the installation:

(1) Conforms to the acceptable methods, techniques, and practices contained in AC 43.13-1A and AC 43.13-2A.

(2) 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) and is functioning properly and safely, and operates in accordance with the manufacturer's specifications.

(3) Is not integrated 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 the Loran 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.

(4) Provides a navigation source annunciator if the Loran-C installation supplies any information to displays such as an HSI or CDI or equipment which are normally used to operate the aircraft.

(5) Except for items (3) and (4) of this paragraph, is completely isolated from all IFR systems.

(6) 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.

APPENDIX 2. SAMPLE FLIGHT MANUAL SUPPLEMENT

APPLICANT
123 FOURTH STREET
ANYTOWN, USA
DOCUMENT #_____

FAA APPROVED SUPPLEMENT TO FAA APPROVED AIRPLANE FLIGHT MANUAL OR PILOT'S OPERATING HANDBOOK AND FAA APPROVED AIRPLANE FLIGHT MANUAL FOR MAKE AND MODEL AIRPLANE WITH MAKE AND MODEL LORAN-C SYSTEM

This supplement must be attached to the applicable "FAA Approved Airplane Flight Manual (AFM), or Pilot's Operating Handbook (POH) and FAA Approved Airplane Flight Manual" when make/model Loran-C system is installed in accordance with technical data approved by FAA Form 337. The information contained herein supplements the information of the basic AFM or basic POH and AFM; for limitations, procedures, and performance information not contained in this supplement, consult the basic AFM or POH and AFM.

This approval is for the following airplane only: REG. NO. _____
SER. NO. _____

FAA APPROVED: _____
(INSPECTOR'S NAME)
Aviation Safety Inspector (Avionics)
AWP-GADO/ACDO/FSDO# _____
Western-Pacific Region
Federal Aviation Administration

FAA APPROVED DATE: _____

INSTALLATION CENTER/FAA REPAIR STATION #_____
123 FOURTH STREET
ANYTOWN, USA
DOCUMENT #_____

SECTION I. LIMITATION SECTION

1. The _____ Loran-C Pilot's Guide dated _____, or later approved revision, must be immediately available to the flightcrew whenever navigation is predicated on the use of the _____ Loran-C system.

2. During RNAV operation of the Loran-C system, other navigation equipment required for the specific type of operation must be installed and operable.

3. During IFR approaches or landings, the Loran-C must not be selected to the pilot's primary navigation display.

4. The _____ Loran-C system is not approved for IFR approaches.

5. No flight operation shall be predicated on the _____ Loran-C system whenever a navigation flag is displayed in the CDI or whenever the Loran-C system annunciates an unreliable navigation condition.

6. The _____ Loran-C system must be checked for accuracy (reasonableness) prior to use as a means of navigation and following any period of dead reckoning or acquisition of a new GRI.

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ANYTOWN, USA
DOCUMENT #_____

SECTION II. NORMAL PROCEDURES

A. General.

Normal operating procedures are described in _____ Loran-C Pilot's Guide dated _____, or later approved revisions.

B. Power Source.

The _____ Loran-C system power source is from the _____ VDC main bus. The system is protected with a _____ amp circuit breaker labeled _____.

C. Aircraft Integration.

1. HSI, CDI, or OBS Interface. The HSI, CDI or OBS will display Loran information when the NAV/LRN switch is placed to the LRN position. This condition is annunciated by a blue LRN light located adjacent to the HSI, CDI or OBS. The HSI, CDI, or OBS will display only the following Loran derived information:

(a) CDI - Left or right course information with full scale of L/R=5.0 nm (en route scale) and 1.25 nm (approach scale).

(b) To/From Symbol - The selected Loran course will take the aircraft To/From the Loran waypoint.

(c) Off/Warning Flag - Loran Navigation is Unreliable.

NOTE: For HSI interfaces that can simultaneously depict a mix of navigational data from Loran and any other source should be completely defined, e.g.

(d) Course Arrow/Course Display - NAV I

(e) Bearing Pointer - NAV 1

(f) Miles Display - NAV 1

(g) Glideslope Indicator - Should be inhibited (Flagged) when Loran is selected.

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ANYTOWN, USA
DOCUMENT #_____

2. Flight Director Interface. To couple the Loran steering information to the flight director steering bars in the ADI:

(a) Place the NAV/LRN switch to the LRN position.

(b) Select the desired course in the HSI, CDI and OBS.

(c) Establish an intercept heading to desired course.

(d) Press the NAV push button on the flight director mode selector panel.

NOTE: A LORAN WARNING FLAG will cause the flight director steering bars to bias out of view.

3. Autopilot Interface. To couple the Loran steering information to the autopilot:

(a) Place the NAV/LRN switch to the LRN position.

(b) ENGAGE THE AUTOPILOT.

(c) Select the desired course in the HSI, CDI and OBS.

(d) Establish an intercept heading to desired course.

(e) Press the NAV push button on the AUTOPILOT mode selector panel.

NOTE: A LORAN WARNING FLAG will cause the AUTOPILOT to revert to the basic autopilot mode (heading hold, pitch hold).

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DOCUMENT #_____

D. Failures and Warnings. The _____ Loran-C system annunciates failures or conditions in which Loran-C Navigation is unreliable in the following manner:

(a) LOW SIGNAL TO NOISE - DESCRIBE
(b) UNACCEPTABLE GEOMETRY - DESCRIBE
(c) EXCESSIVE RANGE - DESCRIBE
(d) BLINK CONDITION - DESCRIBE
(e) CYCLE SLIP - DESCRIBE
(f) STEERING FAILURE - DESCRIBE
(g) ETC. - DESCRIBE

E. Loran-C Operating Areas (LOA's). LOA's specified in the attached charts of this flight manual supplement should be used for planning IFR flights based on the use of the Loran-C system for navigation. LOA's are defined as approximate limits of coverage generally suitable for IFR navigation. The actual areas of suitable IFR navigation will vary as a function of ambient conditions. The warning flag(s) are intended to define the actual limit of approved IFR operation.

F. Computer Program. Means by which the pilot can verify the approved computer program (if provided) should be described and correlated with the approved pilot's guide.

SECTION III. EMERGENCY PROCEDURES - NO CHANGE.

SECTION IV. PERFORMANCE - NO CHANGE.

APPENDIX 3. LORAN-C CHAIN COVERAGE BY TRIAD FOR THE CONTINENTAL U.S., ADJACENT OFFSHORE AREA, AND ALASKA

The table below lists the Loran-C chains and their Group Repetition Intervals (GRI) according to general location. Some chains appear in more than one group. Appendix 3, figures 1 through 7, contain U.S. Coast Guard charts depicting geographical locations of chains listed in the table and the approximate limits of coverage which can be expected for each chain. Actual coverage limits would have to be established by flight testing.

TABLE

AREA OF USE	GRI
Continental U.S.	
Canadian West Coast	5990
Southeastern U.S.	7980
Great Lakes	8970
U.S. West Coast	9940
Northeastern U.S.	9960
Alaska	
Canadian West Coast	5990
Gulf of Alaska	7960
Northern Pacific	9990

NOTE: The charts in this appendix are extracted from the U.S. Coast Guard Commandant Instruction M16562.4, Specification of the Transmitted Loran-C Signal, dated July 1981.

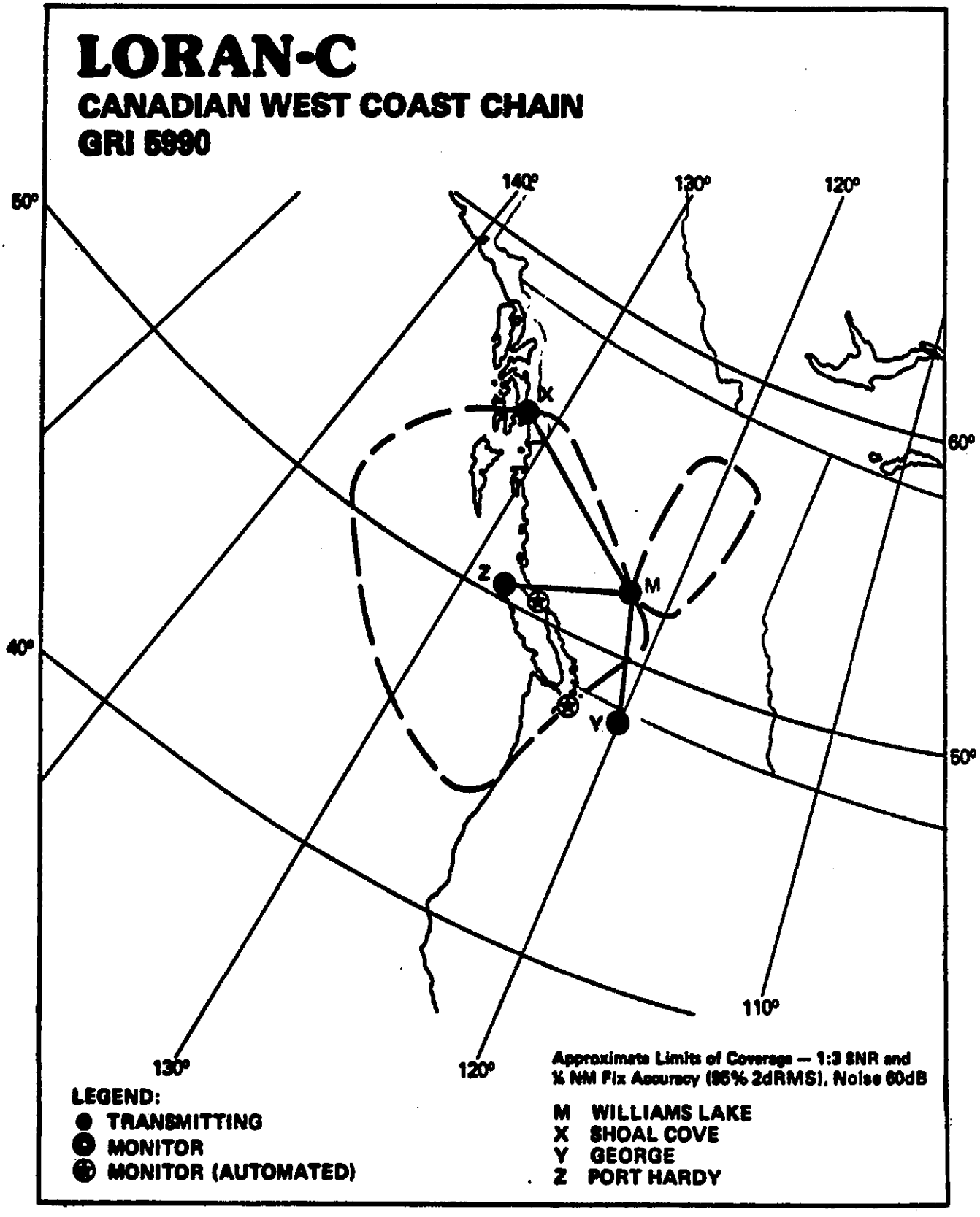
LORAN-C
CANADIAN WEST COAST CHAIN
GRI 5990
140°
130°
120°
50°
60°
40°
110°
130°
120°
X
Z
M
Y
Approximate Limits of Coverage — 1:3 SNR and
½ NM Fix Accuracy (95% 2dRMS), Noise 60dB
LEGEND:
TRANSMITTING
MONITOR
MONITOR (AUTOMATED)
M WILLIAMS LAKE
X SHOAL COVE
Y GEORGE
Z PORT HARDY

FIGURE 1

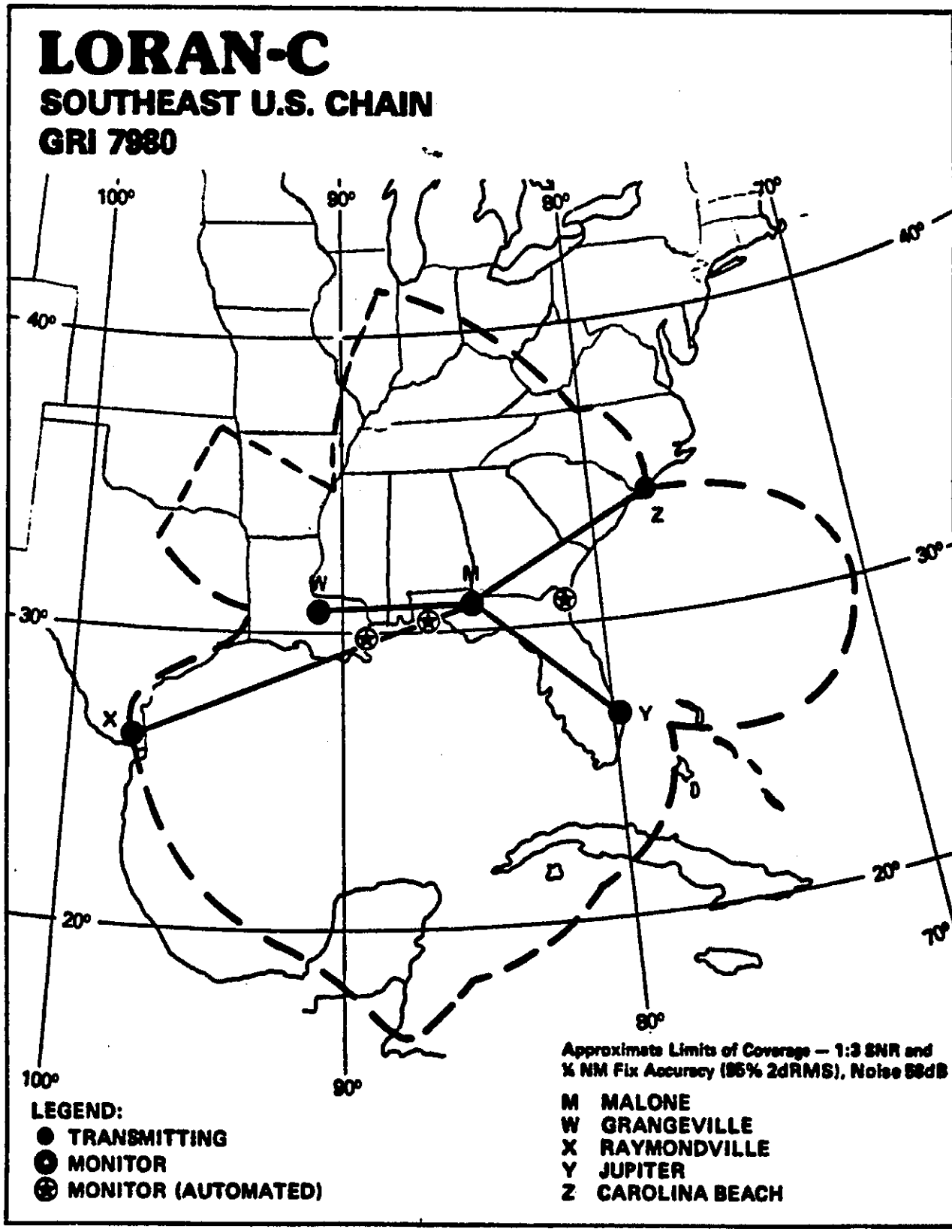
LORAN-C
SOUTHEAST U.S. CHAIN
GRI 7980
100°
90°
80°
70°
40°
30°
20°
M
W
X
Y
Z
Approximate Limits of Coverage — 1:3 SNR and ¼ NM Fix Accuracy (95% 2dRMS), Noise 88dB
LEGEND:
TRANSMITTING
MONITOR
MONITOR (AUTOMATED)
M MALONE
W GRANGEVILLE
X RAYMONDVILLE
Y JUPITER
Z CAROLINA BEACH

FIGURE 2

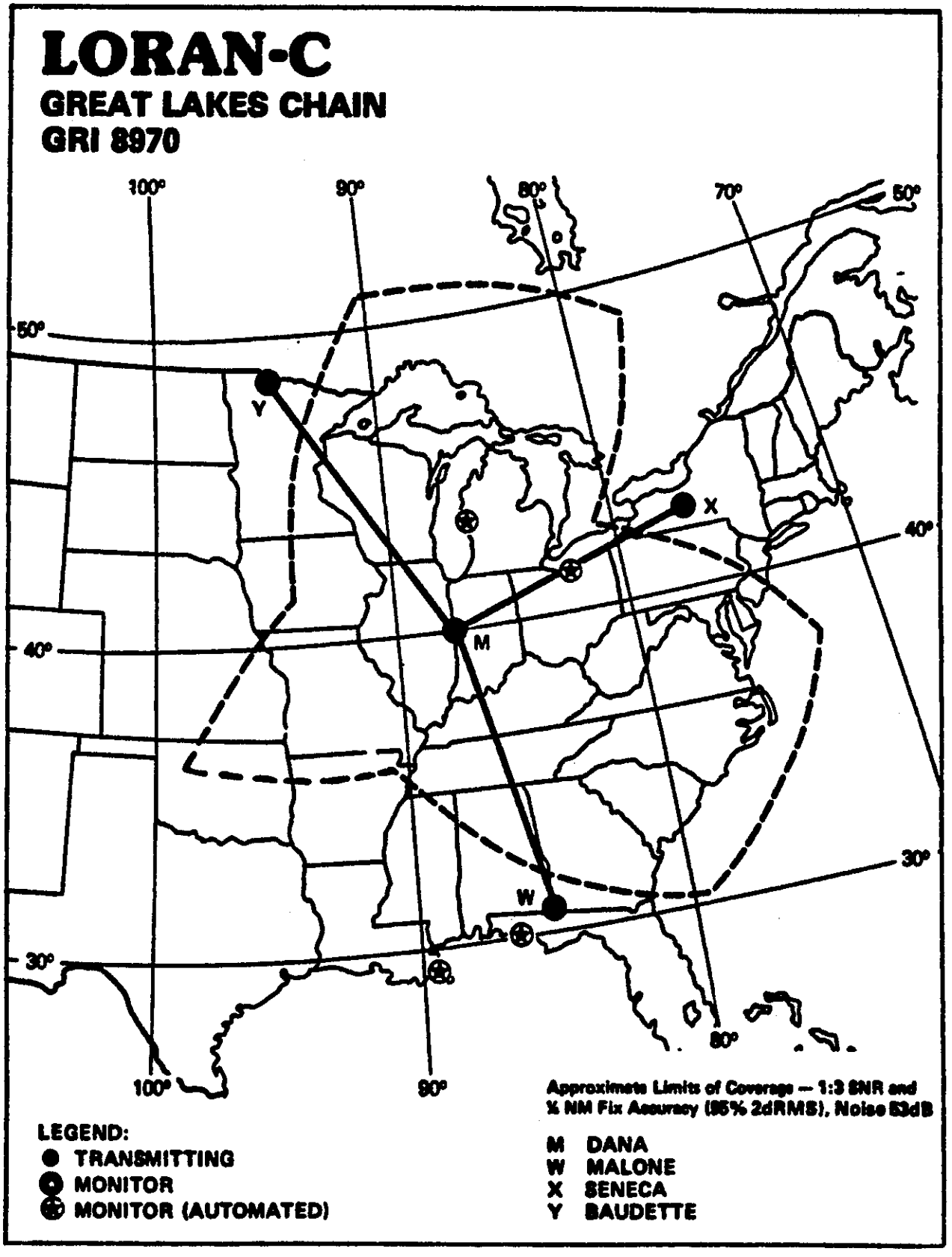
LORAN-C
GREAT LAKES CHAIN
GRI 8970
100°
90°
80°
70°
60°
50°
40°
30°
Y
X
M
W
Approximate Limits of Coverage — 1:3 SNR and
¼ NM Fix Accuracy (95% 2dRMS), Noise 53dB
LEGEND:
TRANSMITTING
MONITOR
MONITOR (AUTOMATED)
M DANA
W MALONE
X SENECA
Y BAUDETTE

FIGURE 3

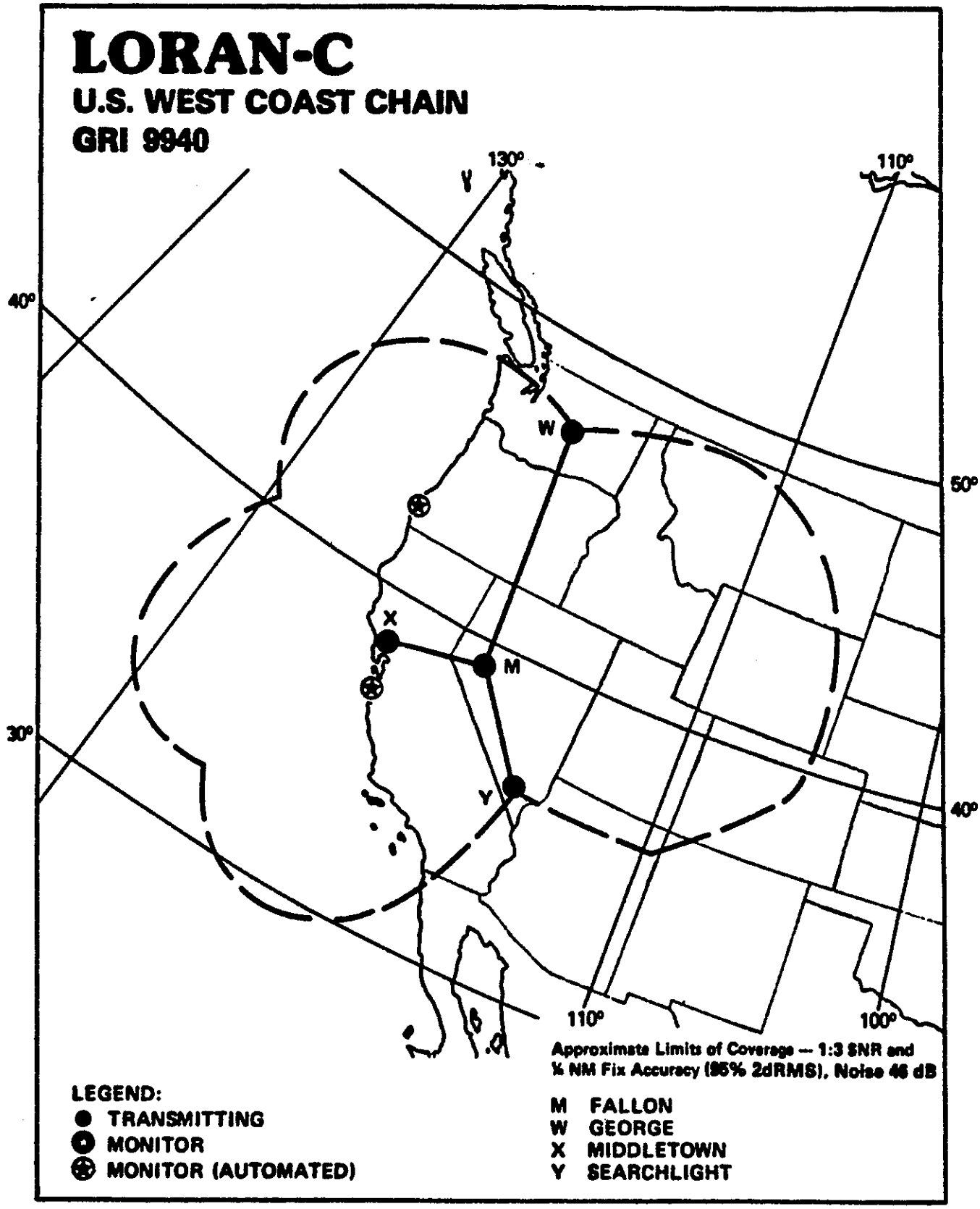
LORAN-C
U.S. WEST COAST CHAIN
GRI 9940
130°
110°
40°
60°
30°
40°
110°
100°
V
W
X
M
Y
Approximate Limits of Coverage — 1:3 SNR and
¼ NM Fix Accuracy (95% 2dRMS), Noise 46 dB
LEGEND:
TRANSMITTING
MONITOR
MONITOR (AUTOMATED)
M FALLON
W GEORGE
X MIDDLETOWN
Y SEARCHLIGHT

FIGURE 4

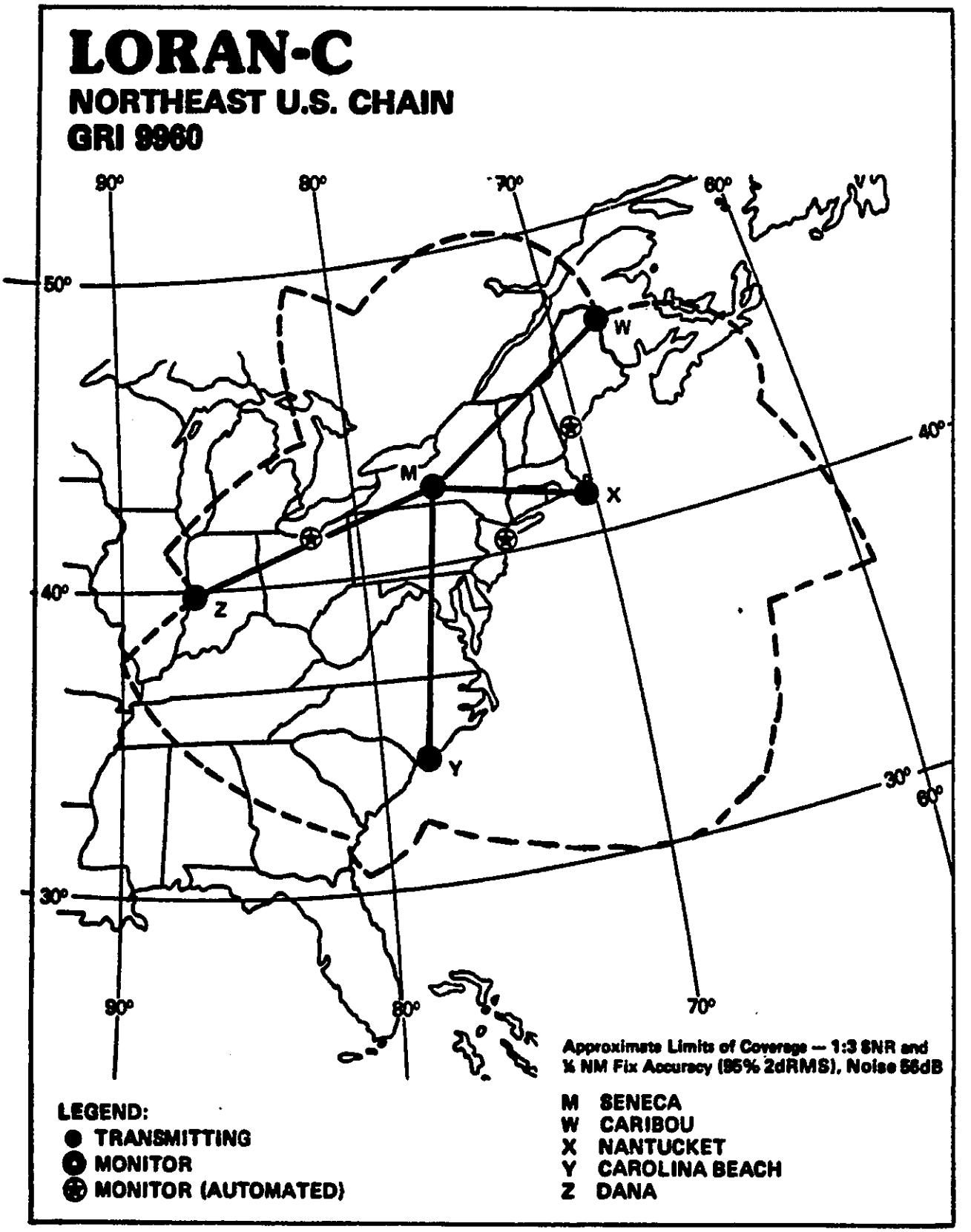
LORAN-C
NORTHEAST U.S. CHAIN
GRI 9960
90°
80°
70°
60°
50°
40°
30°
W
M
X
Z
Y
V
K
Approximate Limits of Coverage — 1:3 SNR and
¼ NM Fix Accuracy (95% 2dRMS), Noise 55dB
LEGEND:
TRANSMITTING
MONITOR
MONITOR (AUTOMATED)
M SENECA
W CARIBOU
X NANTUCKET
Y CAROLINA BEACH
Z DANA

FIGURE 5

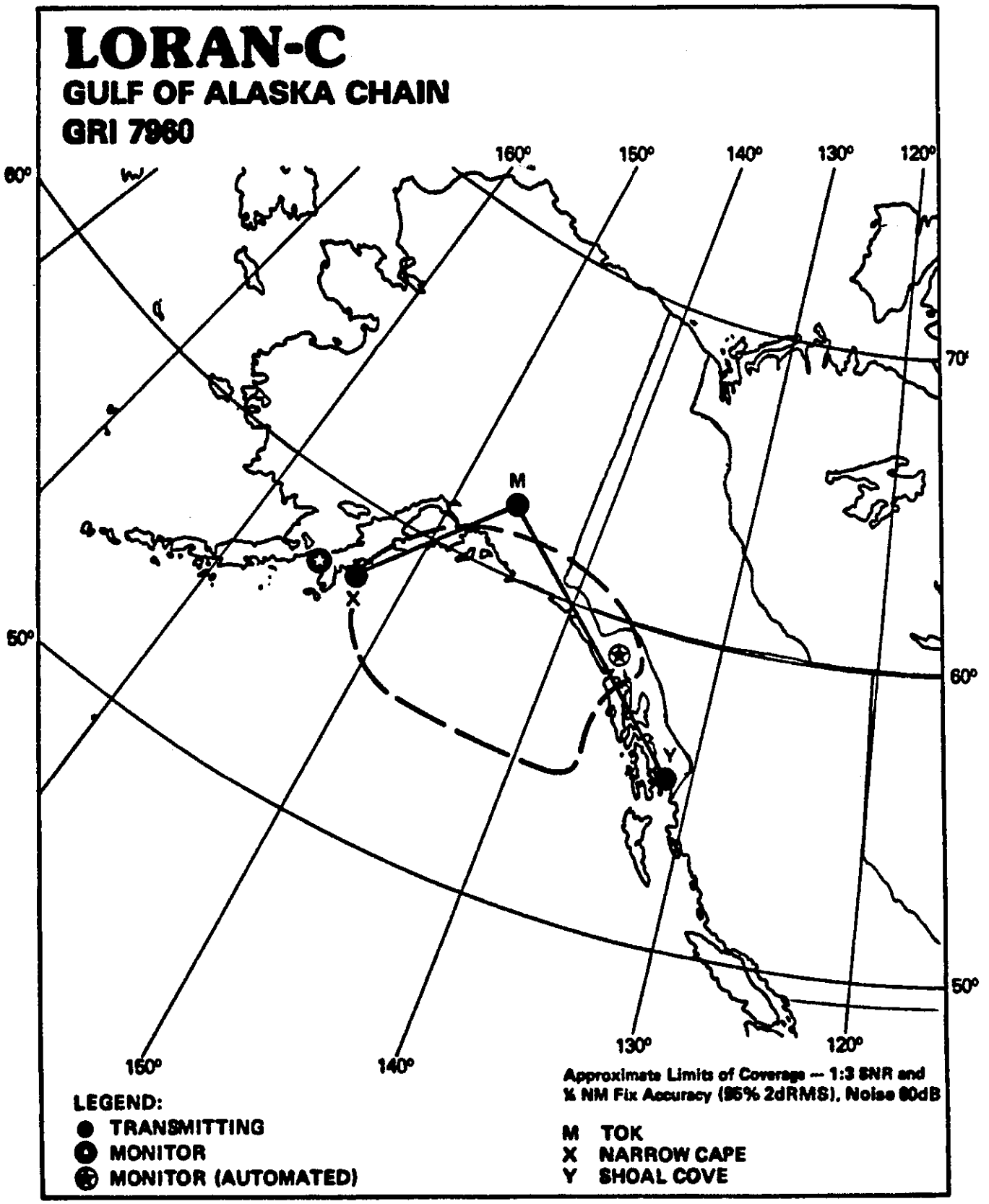
LORAN-C
GULF OF ALASKA CHAIN
GRI 7960
160°
150°
140°
130°
120°
60°
70°
50°
M
X
Y
Approximate Limits of Coverage — 1:3 SNR and
½ NM Fix Accuracy (95% 2dRMS), Noise 60dB
LEGEND:
TRANSMITTING
MONITOR
MONITOR (AUTOMATED)
M TOK
X NARROW CAPE
Y SHOAL COVE

FIGURE 6