

HISTORIC AMERICAN ENGINEERING RECORD

UNITED STATES COAST GUARD
LORAN STATION CAROLINA BEACH, NORTH CAROLINA
LORAN-C TOWERS
STATION LETTER DESIGNATION: S0, SL-0, SS-0, SS-7, 9930-MASTER

Location: 9001 River Road, Wilmington, New Hanover County,
North Carolina
34 03 46.040 N 77 54 46.76 W
Towers: 34 03 55.50 N 77 54 40.40 W
34 03 41 .30 N 77 54 35.10 W
34 03 37.00 N 77 54 52.00 W
34 03 51.10 N 77 57 30.00 W

Date of Construction: 1967 (Loran-C Towers)

Engineers: United States Coast Guard (USCG)

Present Owner: United States Coast Guard (USCG)

Present Use: Loran-C Towers disestablished 2010

Significance: The Loran-C station consists of the only top inverted Pyramid (TIP) Antenna system with four towers constructed as part of the USCG LORAN-C system in the Continental United States. The multi-array TIP-designed towers were constructed in 1967 to replace a prior LORAN-C system at this site. The towers are 625 feet in height and serve as the anchors and the antennas are the wire arrays which link the towers. The LORAN-C station represents the property type "Loran-C Stations Constructed Within the Continental U.S., between 1957-2008" as described in the Multiple Property Documentation Form (MPDF) "United States Coast Guard Loran-C System in the Continental United and was determined eligible for listing in the National Register of Historic Places. As stated in the MPDF the station is significant under Criterion A for its role in navigation and Criterion C as the Only TIP antenna array tower (4) system constructed.

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PROJECT INFORMATION:

This Historic American Engineering Record (HAER) document was undertaken in 2013 in accordance with the Architectural/Engineering Scope of Services 1 (1.1) (1.2) (1.3) (1.5) of the Memorandum of Agreement between the USCG and North Carolina State Historic Preservation Office (NC-SHPO). The four Loran-C towers are scheduled to be dismantled. The format of this report follows the guidelines to HEAR for the recordation of historic structures.

DESCRIPTION:

The Carolina Beach LORAN-C station is located on a tract of land comprised of 210.76 acres and is enclosed by a three strand barb wire fence fronting approximately 3,030 feet on River Road.

The LORAN-C station transmitting antenna is a Top-loaded Inverted Pyramid (TIP), (see Figure 1) supported by four guyed 625-foot towers. The TIP is a multi-array configuration tower design used to transmit LORAN-C signals. The antennas are comprised of the wire arrays connected between the towers, and the towers serve as the anchors. Each antenna tower is a skeletal steel tower, supported with guy wires and the tower is electrically connected to the transmitter and therefore functions as the antenna for broadcasting the radio signal (see Figures 2, 3, 4). From each tower is a ground plane, a conducting surface that operates as part of the antenna to reflect the radiowaves from the other antenna elements. A ground plane comprised of an array of wires buried in the ground and radiate out from the base of the antenna.

Each tower is enclosed with by fencing with a communication hut located near the base of the tower. The towers sit on a concrete foundation. Guy wires are located at 150, 300, 450, and 600-feet on the tower and extend outward. Sidelights are located below the guy wires at the 150, 450, 600-foot level. The antenna cable and backstays are located at 600-foot and a beacon light is at the top of the tower. The antenna cable extends out to the TIP located on the transmitter building (see Site Plans and Engineer Plans, Figures 5, 6)

All towers were constructed at a cost of \$3,000.00 each in 1967. The transmitting antenna measures 3000' x 3000' x 600' (alumiweld cable) and was constructed in 1967 for a cost of \$3,000. The receiving antenna, fiberglass is 42' and cost \$2,000.00.¹

The Carolina Beach LORAN-C station also contains buildings, and these buildings provided a different function for operating the station (see Figure 7).

The Transmitter building was constructed in 1961 at a cost of \$27,000.00. The one-story concrete block building measures 30' x 60'.² Located on the roof of the building are the TIP antenna and the apex of the four antenna wire. The equipment produce the LORAN-C frequency pulse was located in the building (see Figure 8).

¹ "Documentation of Proceedings of a Board Survey, Survey No. BS-32-001-90L," on file with the USCG Carolina Beach Loran-C station, Wilmington, NC.

² Ibid.

The Signal and Power Building constructed in 1953 and is one of the original buildings associated with the establishment of the site. The one-story building measures 40' x 115' and is constructed of concrete block at a cost of \$46,000.³ Housed in this building were the ground station synchronizers, recording, and test equipment. It also contained the principal power source for the station. In addition, this building houses storage rooms, various offices, and shops (see Figure 9).

A new power and signal building was constructed in 1987 at a cost of \$41,000.00. This one-story brick building measures 22'8" x 72'8." ⁴It was constructed to accommodate a new advanced solid-state transmitter. Like other LORAN-C stations, the Carolina Beach station was converted to the modern solid state-state transmitter technology from the original vacuum tube transmitters (see Figure 10)⁵

The Barracks Building constructed in 1974 at a cost of \$56,000. This one-story brick building measures 35' x 80".⁶ This building served as a place for the USCG personal to stay while the station was manned around the clock. Barracks were commonly constructed on LORAN-C stations because the stations were located in rural areas, and required around the clock monitoring. After the automation of the Carolina Beach station, this building was converted to house offices and then used for storage (see Figure 11)

HISTORIC CONTEXT:

General History of Loran

LORAN originated from "Long range Radio Navigation. The LORAN system was developed for military use during World War II and is a pulsed low frequency long-range system of a hyperbolic, terrestrial-based navigation system that is independent of all other navigational aids (navigational log, compass, air-speed meter). LORAN transmitting stations work in pairs. The transmitting stations measures the time-of-arrival variances between two signals transmitted from two geographically separated ground stations. The pulse from the master or first station activates the slave station or the second station into transmitting a similar pulse after a set time delay. Once the navigator of the aircraft or ship knows the elapsed time difference, a LORAN chart is consulted and line of position is selected. The chart is comprised of groups of hyperbolic curves of constant time differences between specific station pairs. The location of the receiver (airplane or ship) will be some place along the curve that relates to the measured time difference. A definite geographic fix may be obtained by selecting a similar time-difference reading from a second pair of stations; curves traverse those of the first pair.⁷

The Long Range Navigation System (LORAN) was invented by Alfred Lee Loomis (November 4, 1897 – August 11, 1975), an attorney and investment banker who was also an amateur scientist. The United States Navy filed a patent on the behalf of Loomis for the LORAN system with the United States Patent and Trademark Office on July 3, 1945. The patent was issued on April 28, 1959 under Patent Number

³ Ibid.

⁴ Ibid.

⁵ Tetra Tech, Inc., "Draft Final: The US Coast Guard's LORAN-C Station at Carolina Beach: A History, (Prepared for the USCG, Civil Engineering Unit Oakland, California), July 2013, 16.

⁶ Ibid.

⁷ W.T. Dickinson, Jansky & Bailey, *Engineering Evaluation of the Loran-C Navigation System: Final Report (report prepared for the U.S. Coast Guard, September 30, 1959).*

2,884,628 (see Figure 1). The origin of the acronym “LORAN” is credited to Lt. Comdr. Lawrence. M. Harding, USCG (1942).⁸ Originally, Loran was called LRN for Loomis radio navigation, but Loomis opposed the system being named after him and it was then changed to LORAN.⁹ The LORAN system was developed by the U.S. Navy in World War II and later transferred to the USCG.¹⁰

In October 1940, Loomis was convinced the research and development of a long-range navigation system was more appropriate for the North American continent over war-ravaged Europe, (as World War II was ongoing in Europe). At the time the British GEE, a short wave pulsed hyperbolic system, was used by the Royal Air Force in World War II, but Loomis envisioned a long-range navigation system based on long waves. LORAN was first developed at the Radiation Laboratory (Rad Lab) of Massachusetts Institute of Technology (MIT) which had contracted with the newly established National Defense Research Committee (NDRC). The navigation project became Project 3 with the Rad Lab. A committee (Microwave Committee) was formed to undertake the development of Project 3. The committee was comprised of Rad Lab representatives, U.S. Government and representatives of Sperry Gyroscope, Radio Corporation of America (RCA) and the British Embassy. A smaller group of researchers led by Melville Eastham commence work on the LORAN system by the summer of 1941. It was decided by Eastham’s group that in order to achieve over-the-horizon operation, a much longer wavelength must be utilized. The group worked quickly and accomplished the basic system by September of 1941 and the group conducted field tests over the next few weeks using medium frequencies.¹¹

The LORAN or LORAN-A system was swiftly developed and immediately pushed into service during WWII. Loran stations were constructed in remote areas and under wartime conditions, which made it a challenging project to undertake. In addition to locating the stations in remote areas, the U.S. had to seek support among the countries where stations had to be located. The first two stations in the North Atlantic Chain were sited on the U. S. Atlantic coast and on the air by June 1942 (Montauk Point, New York and Fenwick Island, Delaware; both were abandon USCG lifeboat stations). In addition, a receiver was installed at Harvard’s Cruft Laboratory and one at MIT’s Graduate House with the main receiver located at Ann Arbor Michigan at the residence of S.A. Goudsmit, scientist. The committee continued to do research and conduct tests between the two stations and the receiver sites. Then a receiver was installed on a station wagon, which traveled to Frankfort, Kentucky and Springfield, Missouri. This part of the test allowed for a controlled examination of the system. Results confirmed that a sky-wave transmission was possible, and it was decided to vacate the original concept of using ultrahigh frequency, a project not based on microwaves.¹²

⁸ *Loran, Volume 1*, “Early Electronic History and the Bridging of the North Atlantic and North Pacific.” U.S. Coast Guard Headquarters, Office of Engineering; Washington D.C., December 1944. (http://www.uscg.mil/history/missions/aton/LORAN/docs/LORAN_Volume_1_Index.asp), Accessed on 13 October 2013.

⁹ Jennet Conant, *Tuxedo Park: A Wall Street Tycoon and the Secret Palace of Science That Changed the Course of World War II*, New York: Simon & Schuster, 2002. 231-232.

¹⁰ Julia Mates, “United States Coast Guard Loran-C System in the Continental United States,” National Register of Historic Places Multiple Property Documentation Form, prepared for U.S. Coast Guard-CEU Providence, 2011, Sec. E:1.

¹¹ Conant, 231-232.

¹² *Ibid.* 233.

Canada was next with a station and by 1943 additional stations was sited in Iceland, Greenland, the Faroe Islands, and the Herbrides completing the North Atlantic Chain. There were 25 stations in the Pacific by the end of WWII, including Jima and Okinawa. The Pacific station Marianas assisted with guidance to the 20th Air Force in the bombing of Japan. Loran stations not only aided in navigation during WWII but also were used to locate airfields for refueling. These stations were manned by USCG, Royal Canadian Navy (RCN), and the Royal Navy (RN).

The first readings using the Loran system from an aircraft was completed on July 4, 1942 during a test flight on a B-24 from Cape Sable, Nova Scotia. The first testing by ship was on the CGC Manasquan from June 17 to July 17, 1942 off of Newfoundland. Both tests revealed good signals, enough to merit expansion of the system.¹³ LORAN receivers were first installed on 7,000 aircraft, and 1,000 ships. By the mid-1940s, over 50,000 receivers had been installed on aircraft and ships.¹⁴

A significant benefit of the LORAN system was that aircraft or ships equipment with LORAN emitted no signal. This allowed ships and aircraft using the LORAN system to navigate without breaking radio silence, which aided ships in dangerous waters, aided aircraft bombers in locating targets, allowed and planes in locating refueling stations. LORAN allowed for daytime, a set fix could be attained up to 700 miles for a transmitting station and up to 1,400 miles at night.¹⁵ At the end of the war, there were 70 LORAN-transmitting stations that provided nighttime assistance to more than 60 million square miles or about 30 percent of the earth's surface. By 1946, 75,000 air-borne and ship-borne navigator receivers had been delivered.¹⁶

The LORAN project cost around \$1.5 million from December 1940 (start of project) until it was finished, a little less than two percent of the investment by the government for the equipment. In addition, \$100 million was estimated for the cost of LORAN systems which included installation, assembly, and shipping.¹⁷

The Rad Lab was officially closed on December 31, 1945.¹⁸

Evolution of the LORAN

The LORAN evolved as improvements were made to the original system during World War II and after. While the original LORAN system provided the military with a much needed navigation system, a more accurate system was desired by the military and outgrowths developed from the original LORAN system.

SS LORAN

When development of the LORAN first started with the Rad Lab, it began as a high frequency system, then it was discovered the system operated best as a low frequency system and became known as the

¹³ Ibid., 404.

¹⁴ U.S. Coast Guard, "The Coast Guard at War, IV. (Available online at: http://www.uscg.mil/history/STATION/loran_volume_2.pdf), (Accessed 10/08/2013).

¹⁵ Conant, 233.

¹⁶ Raymond C Watson, *Radar Origins Worldwide: History of Its Evolution in 13 Nations Through World War II*. Victoria BC, Canada: Trafford Publishing, 2009, 182.

¹⁷ Conant, 272-273.

¹⁸ Ibid., 285.

LORAN or later as LORAN-A. The SS LORAN (Sky-wave synchronized LORAN) was developed from the LORAN, and became heavily utilized during the war when night bombings were being conducted. It was determined skywaves journeyed extremely well over water and land. This realization led to the development of the SS LORAN and it was first operationally used was in 1944. At night time, the skywaves could be split from the groundwaves, allowing the system to function on groundwave or the skywave. To aid in the bombing of Germany, two chains were constructed; one pair from Scotland to Algiers and the second pair located in northern Africa. These stations intersected at right angles over Germany. Later, SS LORAN was expanded into the Pacific.¹⁹ It was discovered that while the LORAN and SS LORAN were extremely useful, there was a need for a new system at a lower frequency which led to the development of a CYCLAN (Cycle Matching Loran).²⁰

CYCLAN and CYTAC

CYCLAN system was developed by the Sperry Gyroscope Company while under contract with the USAF in 1946. The new system operated at frequencies of 180 and 200 kHz and used phase comparison. By the spring of 1945, CYCLAN was ready to field test. Experimental transmitters were installed at Brewster, Massachusetts, near Key Largo, Florida, and Cape Fear (Carolina Beach) North Carolina.²¹ Because the CYCLAN system would not allow for signals to be within the 90-110 kilocycles per second band long-range, a new system, the CYTAC (Cycle Matching Tactical Bombing and Navigation System) was developed.²²

CYTAC was developed around 1952, by the Sperry Gyroscope Company for the USAF which was a direct outgrowth of the CYCLAN project started in 1946 with Sperry Company. The USCG by 1956 required the use of a long-range, high-accuracy radionavigation system which led to the use of CYTAC. This system was a pulsed, hyperbolic navigation system which operated in the 90 to 110 kilocycles per second band long-range, automatic. Eight pulses were transmitted from each station whereas the LORAN transmitted single pulses. By 1955 a station was located at Carolina Beach (Cape Fear) North Carolina, and two stations were sited at Carrabella, Florida and Forrestport, New York:²³

The USCG worked with the Sperry Company for installation and operation of the system aboard the USCG Androscoggin. In April of 1956, a receiver was installed aboard the USCG Androscoggin at Miami Beach, Florida. Testing revealed some changes were needed for the system; those alterations were achieved by the addition of a third tower, making a chain. Additional alterations included improved receiver accuracy and the transmission from the tower to receiver needed to be a lower and longer pulse. Through a little adjustment, CYTAC evolved into the first Loran-C radionavigation system.²⁴

While CYTAC was evolving into the first Loran-C system, another system Loran-B an outgrowth of Loran-A was under development. However, it experienced a short life span (mid-1950s)

¹⁹ Conent, 267.

²⁰ Charles Justice, LT Norm Mason and CDR Doug Taggart, "Loran-C Time Management," U.S. Coast Guard, Radio Navigation Division, USCG Headquarters, Washington, D.C., 80.

²¹ The Carolina Beach, North Carolina station is often referred to the Cape Fear, North Carolina station in written documentation since the station site is located at the end of the Cape Fear.

²² Gifford Hefley, "The Development of Loran-C Navigation and Timing," U.S. Department of Commerce, October, 1972, 8.

²³ Ibid., 109.

²⁴ Ibid.

LORAN-B

Over the years, Loran-A underwent frequent development and modification. However, there was a need to have a superior accuracy than the Loran-A system provided which led to the development work on the Loran-B which never became operational and with the development of LORAN-C it was abandoned.

LORAN-C

While the LORAN-C system was being developed and installed, the LORAN-A stations were still being utilized. A study conducted by the USCG ascertained the LORAN-A and LORAN-C systems could be assimilated which allowed for the sustained coverage at the same time as the completed transition to LORAN-C was accomplished, but it would be a long-term process. Once the LORAN-C was operational outside of LORAN-A, the LORAN-C provided a better navigational fix coverage. In 1958, the integration was undertaken and by 1961 eight stations had been integrated.²⁵

LORAN-C was more accurate than its predecessor and required one “master” station and at least two “slave” stations within each chain. Developed by the United States Navy (USN), LORAN-C was more accurate at ascertaining a ship’s location at sea. The LORAN-C system was put into operation during the time period 1952-1956. The east coast of the United States in 1957 had the first operational chain, followed by chains erected in the Northeast Atlantic and the Mediterranean Sea.²⁶

LORAN-C operates in the 90 to 110 kHz frequency band. It is a low frequency, pulsed hyperbolic radio aid to navigation system. Hyperbolic systems (i.e. lines of position) are hyperbolas; the lines of position are determined by measuring the difference in distance from two points. There is one master station and two slave stations. Because at least two lines of position are required for a fix position, more than one slave station is required. Slave stations are sited roughly 500 – 700 miles away from the master station. To determine the time difference, each station, beginning with the master station, transmits a series of pulses with the following bandwidth of approximately 20 kHz and each station will transmit a series of eight of these pulses; pulse separation is 1000 uS (1ms). It is important to understand that the master station in the majority of chains transmits a ninth pulse after 2000 uS. This helps to indicate the status or integrity of the chain’s signal. To identify the pulses from each station, the stations transmit their signals in sequence. The delay between signals from each station is such that the signal from the previous transmission is out of the coverage area prior to the next one being sent. Therefore, the pulses appear in the same order (see Figure 12 for a list of patents associated with the LORAN-C system).²⁷

LORAN-C Chains are a group consisting of a master and up to four slaves. Each LORAN-C chain is recognized by a Group Repetition Rate (GRI) or the time between transmissions from the master station. Once the master station has transmitted, each slave station transmits its pulse train at a particular

²⁵ Janksy & Bailey, “The LORAN-C System of Navigation” (report prepared for the U.S. Coast Guard, February 1962), 26-27.

²⁶ Ibid., 29.

²⁷ D.E. Blair and A.H. Morgan, “Precision Measurement and Calibration: Selected NBS Papers on Frequency and Time,” NBS Special Publication 300 – Volume 5, Washington D.C.: U.S. Government Printing Office, June 1972, 153-171

interval; this is known as the emission delay (ED) and is comprised of the master-slave time (MS) and a coding delay (CD).²⁸

In LORAN-C Transmitters, the power transmitted has to be high (0.5 to 4 MW) because of the long distance covered by each chain. Since propagation is done by groundwaves, it has to be vertically polarized. This results in the antenna being a vertical mast – preferably a quarter wavelengths long (3km) (10,000 ft.).²⁹

LORAN-C Antennas are normally about 400m in height and all but one station have Top-Loaded Monopole (TLM) antennas. The only station to have a Top Inverted Pyramid (TIP) is located at Carolina Beach, NC.³⁰

LORAN-C Receivers must have a database that provides the location (Lat/Lon) of the master and slave stations, the GRI of the chains to be utilized, and the time delays for each station. The signal travels by groundwave and skywave. Groundwaves are stable and provide reliable timing, whereas, the skywaves do not because of the variable of the ionosphere. Skywave is stronger, and since the groundwave is weaker it can be contaminated by the skywave.³¹

The ground station equipment required for a LORAN-C consists of a transmitting facility which inhabits a land range of roughly one-tenth of a square mile or around one-quarter of a square kilometer. To house the LORAN-C equipment, each site must have two buildings, a transmitter building and a signal and power (operations) building. Located at the base of the transmitting antenna is the transmitter building which hold the equipment required to radiate the LORAN-C pulse. The RF protective screen room with ground station synchronizers, test equipment and related recording equipment, as well as shops, offices, storage rooms, and the primary power source for the station may be located in the signal and power (operations) building.³²

Every LORAN-C transmitting station essentially has a transmitter synchronizer, a high-powered pulse transmitter and related equipment. While the transmitters and the synchronizers at each station are capable of executing the identical functions, the synchronizers at the master stations are operated in different methods than those at a slave stations. In addition, each station has two synchronizers, two transmitters, control and switching equipment, a transmitting antenna and a receiving antenna. In standard station procedure, one synchronizer and one transmitter were utilized to provide on-air operation. In order to safeguard high consistency operation, the other set was placed on standby readiness; the standby set likewise was used to perform monitoring functions.³³

By 1962, four stations were constructed in the continental U.S., not including those constructed in Alaska. These included those at Wildwood, New Jersey (c.1957), Carolina Beach, North Carolina (c. 1961), Nantucket, Massachusetts (c. 1961), and Jupiter, Florida (c.1962).³⁴ (see Figure ?? for a map of LORAN-C locations)

²⁸ Ibid.

²⁹ Ibid.

³⁰ Mates, F:12.

³¹ Blair, 153-171.

³² Jansky 80 .

³³ Ibid.

³⁴ Mates, F: 12.

Closure of LORAN-C

The U.S. Office of Management and Budget released the first blueprint for the Financial Year 2010 budget on 26 February 2009. This document identified the LORAN-C system as “outdated” and encouraged its termination for an estimated savings of \$36 million in 2010 and \$190 million over five years.³⁵

President Barack Obama proposed cutting funding (approx. \$35 million/year) for LORAN, citing its redundancy alongside GPS on 7 May 2009, a few months after the release of the financial budget for 2010 was released. The proposed plan called for the decommissioning of the LORAN system to start in January 2010. In addition, the plan required that certifications be provided to document that the LORAN-C termination will not impair maritime safety or the development of possible GPS backup capabilities or needs.³⁶

On October 28, 2010, the Department of Homeland Security Appropriations Act was signed into law. It instructed the USCG to discontinue LORAN-C with the proviso that specific circumstances were met. USCG Commandant Admiral Thad Allen had to certify the termination of LORAN-C signal would not adversely impact the safety of maritime navigation and Department of Homeland Security Janet Napolitano had to certify that the LORAN-C system infrastructure was not required as a backup to the GPS system or to meet any other Federal navigation requirement. Those certifications were made and the USCG commenced forward with proposed plans to for phased decommissioning of the LORAN-C system around February 8, 2010.³⁷

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The LORAN-C system served 48 continental states as well as their coastal areas, portions of Alaska, and neighboring countries. The LORAN-C signal was maintained and operated for 67 years, 8 months, and 24 days (see Figures 13 and 14 for LORAN-C stations locations).

In addition to LORAN-A, LORAN-B and LORAN-C, there were two other variations of the LORAN, LORAN-D and LORAN-F. USAF used LORAN-D as a bombing aid; the tactical system was a short range, high accuracy, and low power system. While the USAF was working on the development of LORAN-D,

³⁵ Ed Henry, “Navigation System, aid to farmers among budget cuts,” *CNN Politics.com*, 26 Feb. 2009. Available online at: (<http://www.cnn.com/2009/POLITICS/02/26/budget.cuts/>), (Accessed 15 Oct. 2013).

³⁶ Ibid.

³⁷ “Terminate Long Range Aids to Navigation (Loran-C) Signal,” Department of Homeland Security, Coast Guard (Docket No. USCG-2009-0299), *Federal Register*, Vol. 75, No. 4, Thursday, 7 January 2010. (Available online at: http://www.navcen.uscg.gov/pdf/loran/geninfo/USCG_FRDOC_0001-1185.pdf), (Accessed on Oct. 2013).

³⁸ Ibid.

another system was being tested, LORAN-F, a Multi-User Tactical Navigation Systems (MUTNS). This system was never officially designated as LORAN-F. The system was a continual pulsed pseudorandom code low frequency navigation system utilized for drone control. LORAN-F did not fare as well as the LORAN-D system and the study was discontinued.³⁹

Global Positioning System

Global Positioning System (GPS) is a space-based satellite navigation system comprised of a network of 24 orbiting satellites, U.S. owned and placed in orbit by the U.S. Department of Defense. GPS provides positioning, navigation and timing (PNT) services. There are three segments which make up the system: the space segment, the control segment, and the user segment. The USAF maintains, operates the space and control segments, as well as development.

The Space Segment contains a nominal constellation of 24 operating satellites. The satellites transmit one-way signals that provide the current GPS satellite location and time.

The Control Segment are comprised of world-wide monitor and control stations. These stations maintain the satellites in their proper orbits by regular command maneuvers, and adjust the satellite clocks. The Control Segment uploads updated navigational data, tracks the GPS satellites, and maintains the status of the satellite constellation.

The User Segment has GPS receiver equipment that receives the signals from the GPS satellites then utilizes the transmitted information to calculate the user's three-dimensional position and time.

GPS service is provided to military users as well as civilian users. The military services are available to U.S. and allied armed forces, in addition to approved government agencies. Civilian services are available on a world-wide basis.⁴⁰

History of LORAN Station Carolina Beach, North Carolina

The Carolina Beach LORAN station dates to 1946 and is located on 210.76 acres. Due to the proximity of the station's location near the end of the Cape Fear River, it was also known as the Cape Fear station in early documentation of the site. According to the original final project map of the site, the station is located 10 miles south of Wilmington, North Carolina. (see Figures 15, 16) Carolina Beach is roughly three miles south of the station.

As stated earlier, prior to being designated a LORAN-C station, this site was one of the original testing locations for Low Frequency (LF) LORAN or CYCLAN (1945) and a long range tactical system, CYTAC (1957). In 1945, the first experimental LF LORAN system was put into operation with transmitting stations located at Cape Cod, Massachusetts, Carolina Beach (Cape Fear), North Carolina, and Key Largo, Florida. The overwater observations monitor stations were located at Puerto Rico, Trinidad, Bermuda,

³⁹ Walter Dean, "How We Got to Where We Are," Presentation at the First Annual Wild Goose Technical Symposium (edited transcription of a tape recording), 24-27 August 1992, (no pages numbers listed), (Available online at: <http://www.loran.org/Meetings/Meeting1972-1992/WildGooseAssociation12-14October1983.pdf>), (Accessed on 10 Oct 2013).

⁴⁰ "The Global Position System," (Available online at: <http://www.gps.gov/systems/gps/>), (Accessed on 1 November 2013).

and the Azores. The overland signals were watched at Minnesota and Ohio, as well as aboard specially equipped aircraft.⁴¹

As with the majority of LORAN stations when first established, the Carolina Beach station was located in a rural area. The site met the requirements set forth for LORAN stations; 75 acres of open at minimum, level land (to have capacity to house a 625-foot antenna), and the land grade must have been less than 10 percent within the antenna location (850-foot radius). In addition, the contiguous topography had to be barren of hills, and bluffs; predominantly in the direction of the paired station(s) and the service area. Other factors that contributed to the location of a LORAN station were the type of vegetation, soil, atmospheric noise, ground conductivity, and signal strength capacity. The acquisition and purchase of the acreage for a LORAN site was not undertaken until the survey was finalized and site was authorized.⁴² Final project map for the Carolina Beach station was signed off on May 4, 1951, giving clearance to start acquisition of property for the site (see Figure 17).⁴³

In 1951, the United States of America on behalf of the USAF began the acquisition process of acquiring the 210.76 acres (located in the Federal Point Township) of the current site to house the CYTAC system, later referred to as LORAN). On September 8, 1951, a Declaration of Taking was filed for 195.68 acres of landed owned by Robert Bruce Freeman Estate (known as Tract 1); estimated just compensations: \$9,320.00. On Oct 10, 1951, a warranty deed was filed for 5.47 acres (Tract 4) of land owned by Ellis G Freeman Estate; estimated just compensations \$400.00. The warranty deed for the acquisition of Tract 5 of 2.79 acres owned by J.R. Lewis Estate; estimated just compensations \$500.00 was filed on October 10, 1951. Tract 6, 10.31 acres from the Eliza Belle Hall Estate was acquired for \$500.00 (no date on paperwork). On December 17, 1951, 1.79 acres (Tract 2) was acquired from the Roland V. Freeman Estate for \$100.00.⁴⁴

By 1955, a CYTAC station was located at the Carolina Beach station and was one of three transmitting stations. The other two stations were located at Carrabelle, Florida and Forestport, New York. (see Figure 14, for CYTAC and monitoring stations map) In 1956-1957, the Carrabelle station was relocated to Jupiter, Florida (slave station) and the Forestport, New York station was relocated to Martha's Vineyard (slave station); the Carolina Beach station was retained as the master station.⁴⁵ In January of 1957, the USCG agreed to take part in a project which was sponsored by the Navy Special Projects Group of the Bureau the Ordnance to provide navigational calibration service for Project JUPITER. In order to offer this service, LORAN type electronic equipment formerly utilized with the CYTAC project had to be installed and operated for roughly one year at all stations located along the east coast of the U.S. One of the transmitting stations was Carolina Beach (Cape Fear) with the other two stations located at Jonathan Dickinson State Park, Florida and Martha's Vineyard, Massachusetts with the ground monitor station located at the USN station in Bermuda. The contractor Sperry Gyroscope Company was to be on site from January-April of 1957. In April of 1957, CYTAC was disestablished at the Carolina Beach station and the Loran Transmitting station was re-established. The Corps of Engineers, U.S. Army granted the USCG a permit to occupy and utilized the experimental LORAN transmitting station at the Carolina Beach (Cape Fear) station on May 1, 1957. For the first six months after the site was in operation, the USCG

⁴¹ Janksy, 10-12.

⁴² Janksy, 145-153.

⁴³ Final Project Map, on file with the USCG LORAN-C, Carolina Beach, NC.

⁴⁴ Declaration of Taking Deed and Warranty Deed, New Hanover County, on file with the USCG LORAN-C Carolina Beach station, Wilmington, NC.

⁴⁵ Janksy, 13-14.

personal was trained by Sperry personal on the equipment.⁴⁶ Then in August of 1958, the USCG in accordance with the U.S. Federal laws assumed accountability for operations of the stations. It was at this time that LORAN-C was designated and placed into operational level.⁴⁷

Originally, the Carolina Beach LORAN-C station housed a single 625-foot antenna tower but it received severe damage on September 28, 1958 by Hurricane Helene. The station was hit by winds of 125 miles per hour and gusts of 150 to 160 mph, and the top 250-feet of the antenna tower was taken out (see Figure 18, 19, 20). According to the USCG report dated October 3, 1958, no personal were injured and the following damage was done to the station:

- 625-foot transmitting antenna tower destroyed;
- 90-foot LORAN remote receiving antenna tower destroyed;
- Communications antennas blown down;
- Damage to the operation building, damaged or lost shingles, punctured shingles, hole in roof (6 x 6 inches), chimney ventilator blown off but reusable;
- Damage to the utility building, a corner of the building was struck by a falling cable and causing the corner to be open to the elements;
- Two surplus power transformers crushed by tower; and
- Cyclone Fence, one 12 foot section and one gate half destroyed, some minor damaged from a falling cable.

The damage from Hurricane Helene led to demolition of the towers; salvage value was \$24,995.00. A new 625-foot tower was erected in the spring of 1959 which was supported by guy wires at a cost of \$220,000, which included obstruction lights, antenna system, hoist engine and house, 4 (65') wood poles and a small steel tower (see Figures 21).⁴⁸ The first-hop skywave from Carolina Beach Station, North Carolina to Boulder, Colorado, was conducted in 1961 (see figures 22, 23, 24). The single tower would have a short life span, when in 1966; a new antenna array was installed to transmit LORAN-C signals. The system, TIP, was the only to be installed at a LORAN-C station. It was thought the TIP system would have been more efficient but this was not the case. The system was comprised of a TIP-designed antenna array of four 625-foot towers. The towers were installed with 1,500 feet of wire extending between each tower, these wires served as the antenna while the towers served as the anchors. Each wire then connected to the TIP located on the transmitter building (see Figures 1, 2, 3, 4).⁴⁹

The LORAN-C system continued to operation at the Carolina Beach station until it was disestablished in February 2010 (see Figures 13 and 14 for LORAN-C stations locations), (see Figures 26,26,27,for LORAN-C chains in the U.S).

⁴⁶ USCG Documents, on file with the USCG LORAN-C Carolina Beach Station, Wilmington, North Carolina.

⁴⁷ Jansky, 13-14.

⁴⁸ Requisition and Invoice/Shipping Document, 22 October 1958, on file with the USCG Carolina Beach LORAN-C station, Wilmington, NC.

⁴⁹ Mates, F:12-13.

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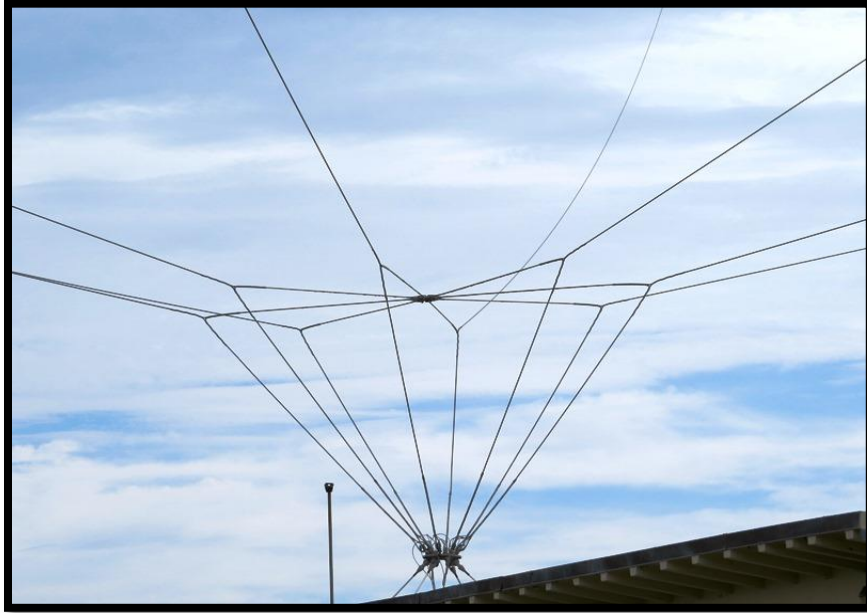


Figure 1. Top-Inverted Pyramid (TIP) with apex of wires, USCG Carolina Beach LORAN-C station, Wilmington, NC.

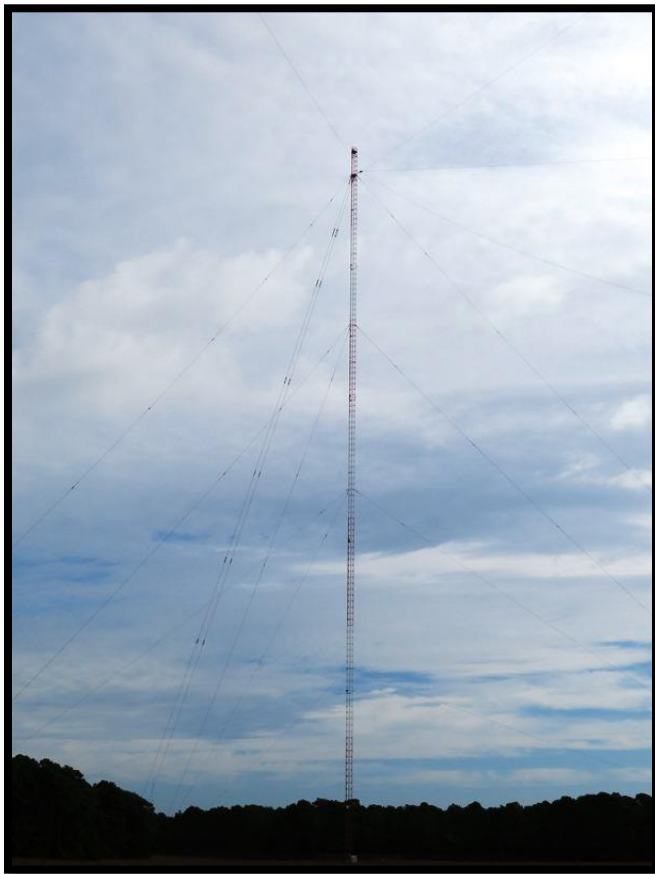


Figure 2. LORAN-C Tower (TL2), USCG Carolina Beach LORAN-C station, Wilmington, NC.



Figure 3 and 4. Top of LORAN-C tower (TL1), and tower base (TL4), USCG Carolina Beach LORAN-C station, Wilmington, NC.

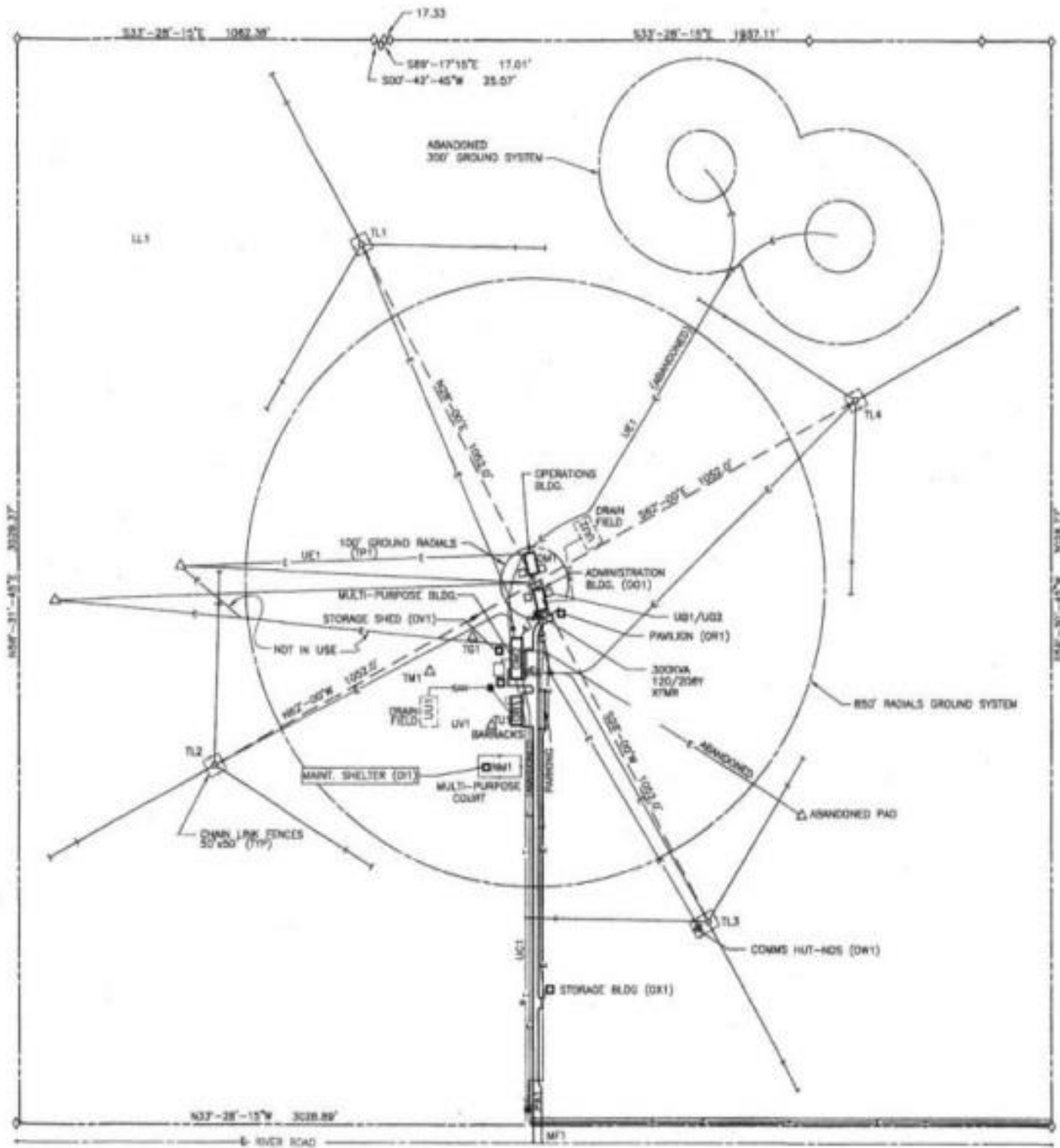


Figure 5. Site Plan, USCG Carolina Beach LORAN-C station, Wilmington, NC. Source: USCG Civil Engineering Division, Cleveland, OH.

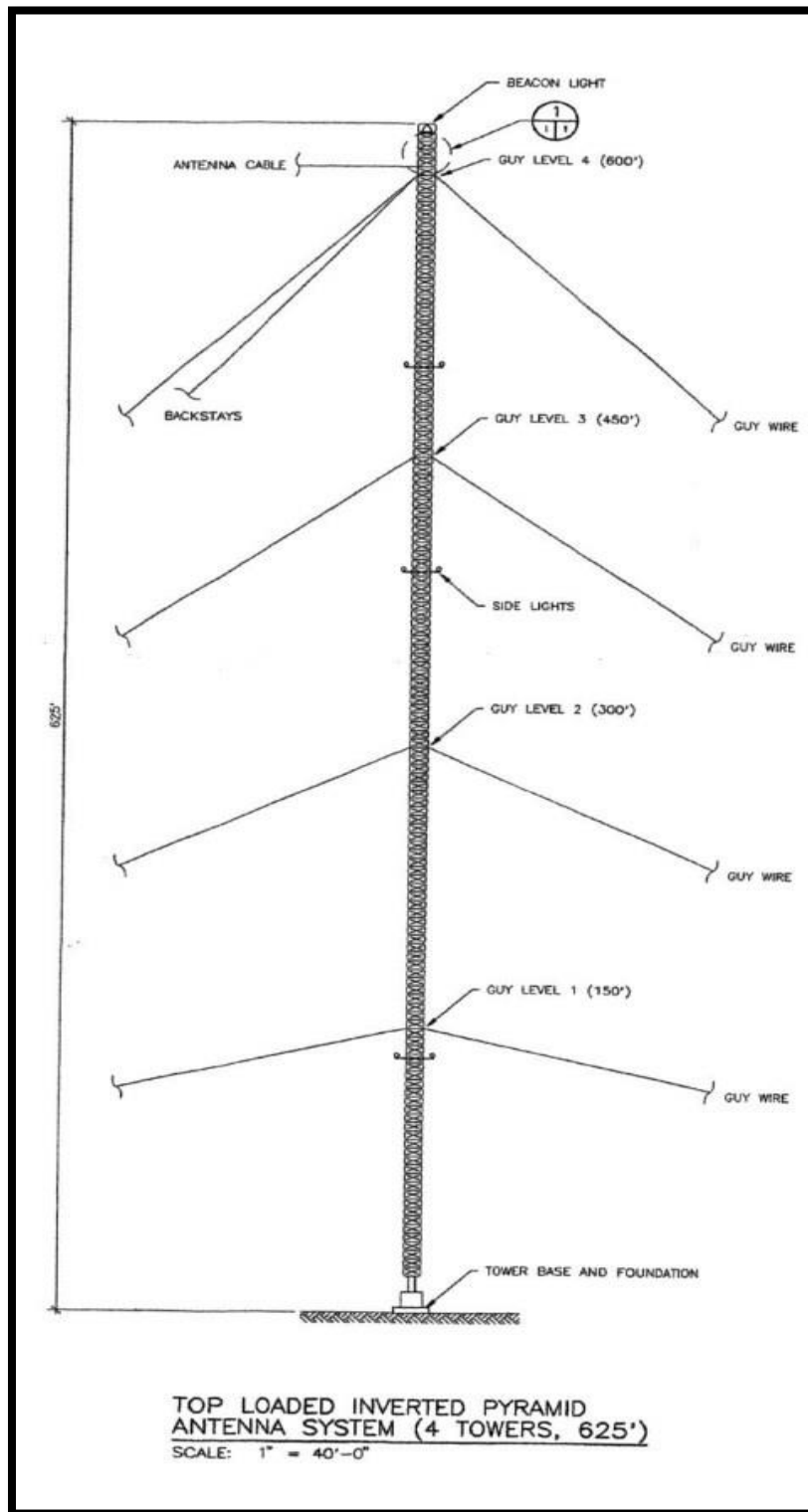


Figure 6. LORAN-C Tower, USCG Carolina Beach LORAN-C station, Wilmington, NC. Source: USCG Civil Engineering Division, Cleveland, OH.



Figure 7. Showing landscape view of station site with buildings and tower 1 in the background.



Figure 8. Showing the Transmitter building (C. 1961) with TIP antenna and apex of wires; new Signal and Power building (c. 1987) located to the rear of the transmitter building.



Figure 9. The Signal and Power building (c. 1953)



Figure 10. The Barracks building (c. 1971)

April 28, 1959

A. L. LOOMIS

2,884,628

LONG RANGE NAVIGATION SYSTEM

Filed July 3, 1945

6 Sheets-Sheet 1

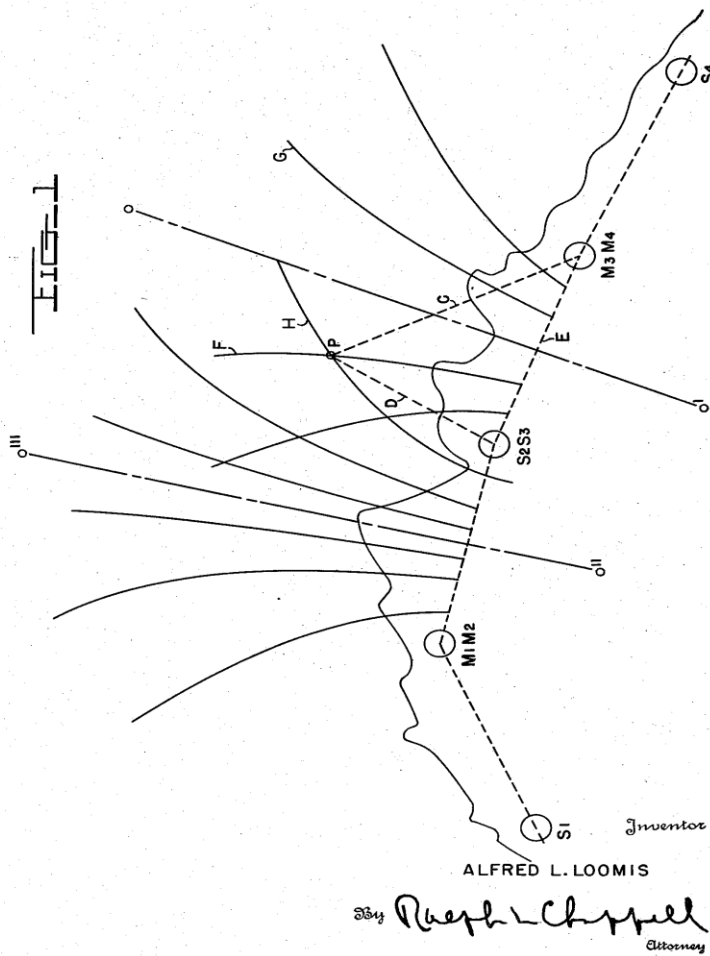


Figure 11. Patent for the LORAN system, filed on July 3, 1945; awarded on April 28, 1959. Source: United States Patent and Trademark Office. (Available online at: <http://patft.uspto.gov/>).

Patent No.	Date	Type of Patent
2811716	Oct. 29, 1957	Phase Responding Apparatus
2811717	Oct. 29, 1957	Automatic Phase Comparator Apparatus
2811718	Oct. 29, 1957	Automatic Tracking LORAN Receiver
2835888	May 20, 1958	Multiple Pulsed Navigation System
2873445	Feb. 10, 1959	Hyperbolic Navigation Receiver
3034119	May 9, 1962	Automatic Gain Control System
3044064	July 10, 1962	Hyperbolic Navigation Receiver
3079601	Feb. 26, 1963	Delay Generator
3153237	Oct. 13, 1964	Signal Processing Apparatus
3167771	Jan. 26, 1965	Blanking Circuit Synchronized with code for Balancing Detector Interference
3319250	May 9, 1967	Double Gate Pulse Matching System LORAN Receiver
3325809	June 13, 1967	Synchronous Interference Rejection System for Receivers of Phase Coded Carrier Signals
3325810	June 13, 1967	LORAN-C Cycle Selection System
3332079	July 18, 1967	LORAN-C Cycle Matching Apparatus
3337723	Aug. 22, 1967	Integrating Data Converter to Provide Continuous Representation of Aircraft Position
3343169	Sept. 19, 1967	LORAN Control and Timing Circuits
3358283	Dec. 12, 1967	Radio Navigation System
3371346	Feb. 27, 1968	Pulse Segment Identifier
3375520	Mar. 26, 1968	Integrated Navigation Receiver
3422433	Jan. 14, 1969	LORAN Receiving System
3453551	July 1, 1969	Pulse Sequence Detector Employing a Shift Register Controlling a Reversible Counter
3611383	Oct. 5, 1971	Instantaneous Predictive Automatic Gain control Circuit Useful in LORAN Navigation
3706092	Dec. 12, 1972	Electronic Instrument Servo
3714656	Jan. 30, 1973	Digital Signal Processor for Use in a Hyperbolic Radio Navigation Receiver
3731207	May 1, 1973	System for Identifying Phase Coded Groups of Radio Frequency Signals
3736590	May 29, 1973	LORAN-C Receiver
3743754	July 3, 1973	LORAN Signal Synthesizer
3806933	April 23, 1974	Pulsed Hyperbolic Receiving System
3821743	June 28, 1974	Ferrite Loopstick Antenna Arrays for LORAN-C Receiver
3858216	Dec. 31, 1974	Method and Apparatus for LORAN Reception
3868691	Feb 25, 1975	LORAN Receiver Automated Master Search
3921076	Nov. 18, 1975	Method of and Apparatus for Locating Predetermined Portions of a Radio-Frequency Pulse
3934254	Jan 20, 1976	Reliable Cycle Selection in LORAN-C System
3944789	Mar. 30, 1976	LORAN Receiver Navigator
4024383	May 17, 1977	Method and System for Navigation Employing Incremental Range Difference
4134117	Jan. 9, 1979	LORAN-C Receiver
4166275	Aug. 28, 1979	LORAN Receiver System

Patent No.	Date	Type of Patent
4268830	May 19, 1981	Self-Calibration of a LORAN-C Navigation Receiver
4214245	July 22, 1980	LORAN-C Navigation Apparatus
4224623	Sept. 23, 1980	LORAN-C Signal Processor
4268830	May 19, 1981	Self-Calibration of a LORAN-C Navigation Receiver
4318105	Mar. 2, 1982	LORAN-C Navigation Apparatus
4325068	April 13, 1982	LORAN-C Signal Processor
4370748	Jan. 25, 1983	Apparatus and Method for Detecting the Presence of a Pulsed Radio Frequency Signal
4468668	Aug. 28, 1984	Method for Processing Signals in a Navigation Receiver
4482896	Nov.13, 1984	Differential ECD Detector for LORAN-C Receiver
4543580	Sept. 24, 1985	System for Lightning groundstroke Position by Time of Arrival
4591860	May 27, 1986	LORAN-C Receiver
4594594	June10, 1986	LORAN Signal Receiver
4743912	May 10, 1988	Method of and apparatus for reducing cycle slippage errors in Loran-C and similar radio-frequency signal reception
4474518	Sept. 27, 1988	LORAN-C Signal Phase Tracking Apparatus
4804964	Feb. 14, 1989	LORAN-C Signal Phase Receiving Apparatus

Figure 12: List of Patents Associated with LORAN-C system. Source: U.S. Patent and Trademark Office. (Available online at: <http://www.uspto.gov/patents/>).

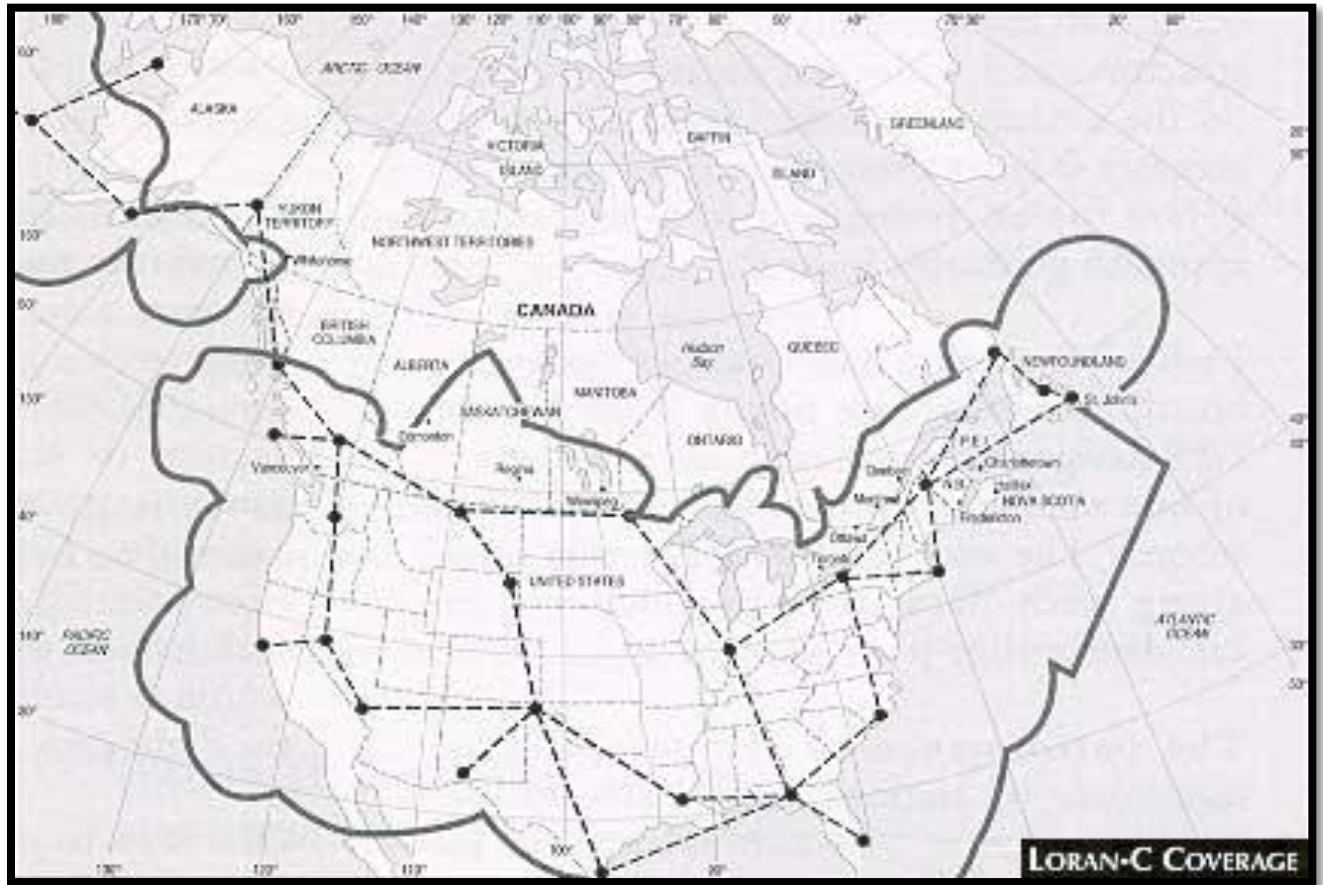


Figure 13: Map showing LORAN-C coverage. Source: Florida International University (Available online at: <http://www.allstar.fiu.edu/aero/rnav.htm>).



Figure 14. Map showing LORAN-C stations, 2010. (Available online at: <http://www.cnn.com/2010/TECH/02/08/loran.navigation.shutdown/>).

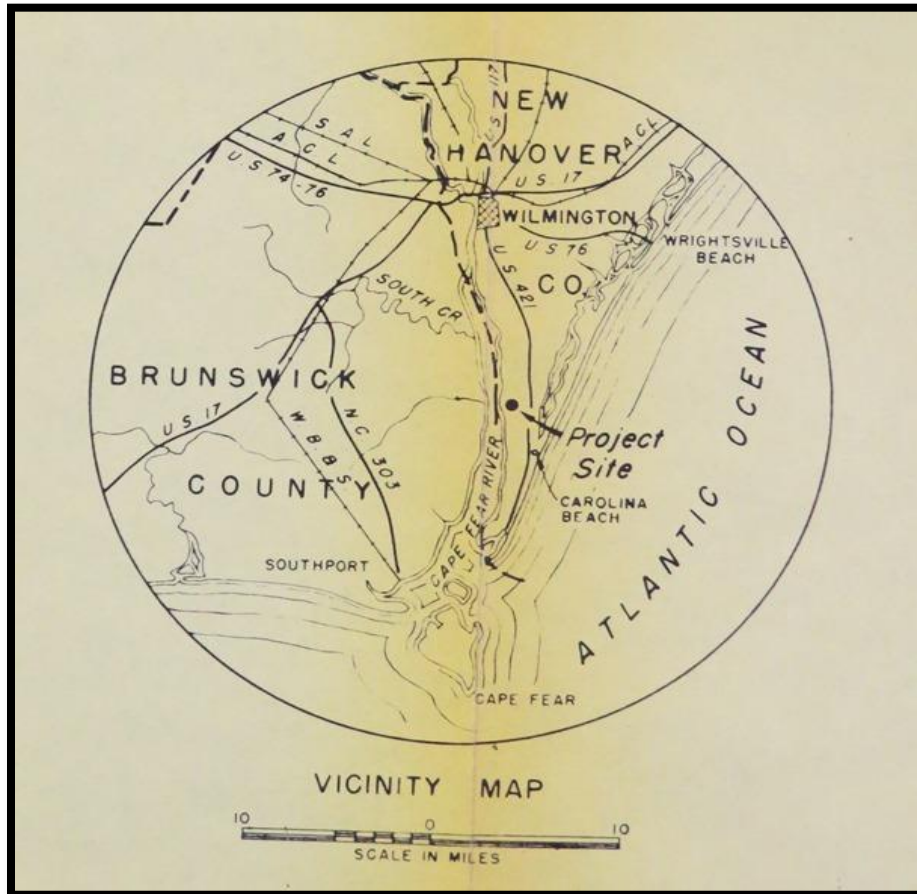


Figure 15. Map showing location of Carolina Beach LORAN-C station (1951) Source: Final Project Map, 4 May, 1951, on file with the USCG Carolina Beach LORAN Station



Figure 16. Map of USCG Carolina Beach LORAN-C station with buildings and towers. Source: Bing Maps.

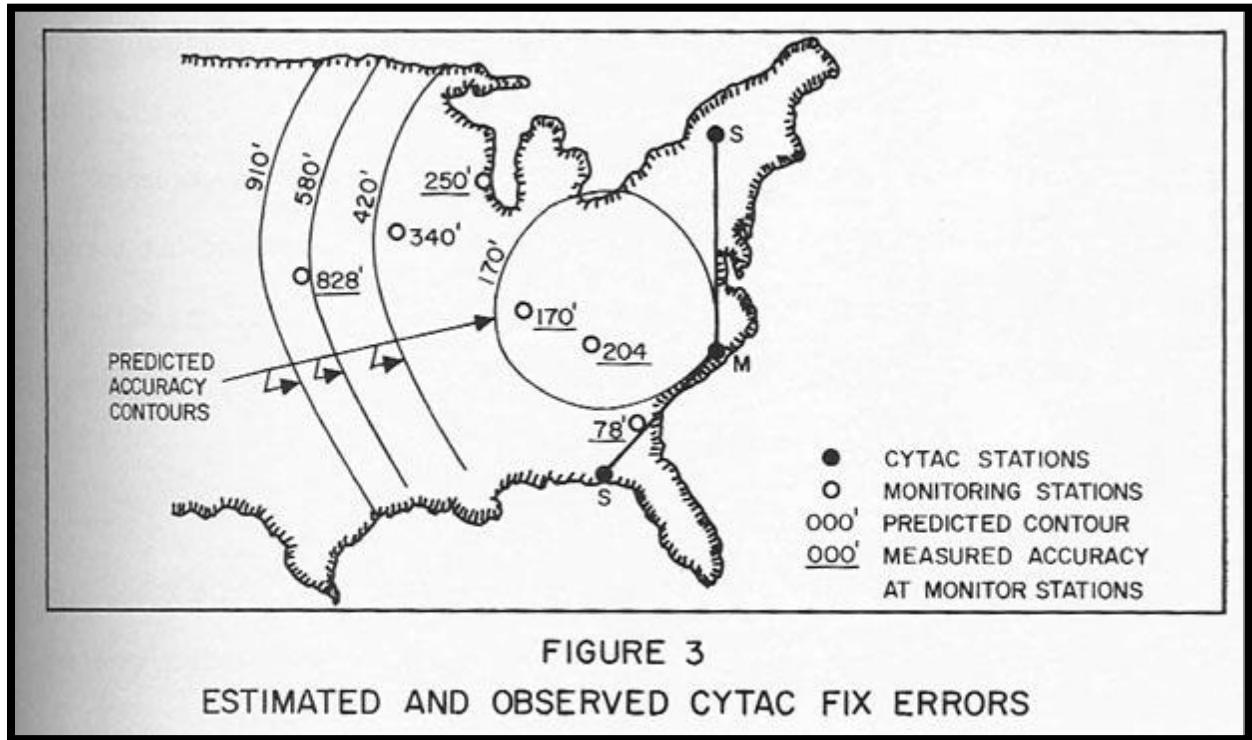


Figure 17. Map showing CYTAC stations. Source: Jankys & Bailey, "The LORAN-C System of Navigation" (report prepared for the U.S. Coast Guard, February 1962), 13.



Figures 18 and 19. Hurricane Helene photographs. Picture on the left shows upper section of the tower has been broken; Picture on the right depicts the top third of the tower on the ground. Source: USCG website available at: http://www.loran-history.info/carolina_beach/carolina_beach.htm



Figure 20. USCG Carolina Beach LORAN Station, Sept. 1958. (Available online at: http://www.loran-history.info/carolina_beach/carolina_beach.htm).



Figure 21. Photo showing the single guyed tower (c. 1959). (Available online at: http://www.loran-history.info/carolina_beach/carolina_beach.htm).

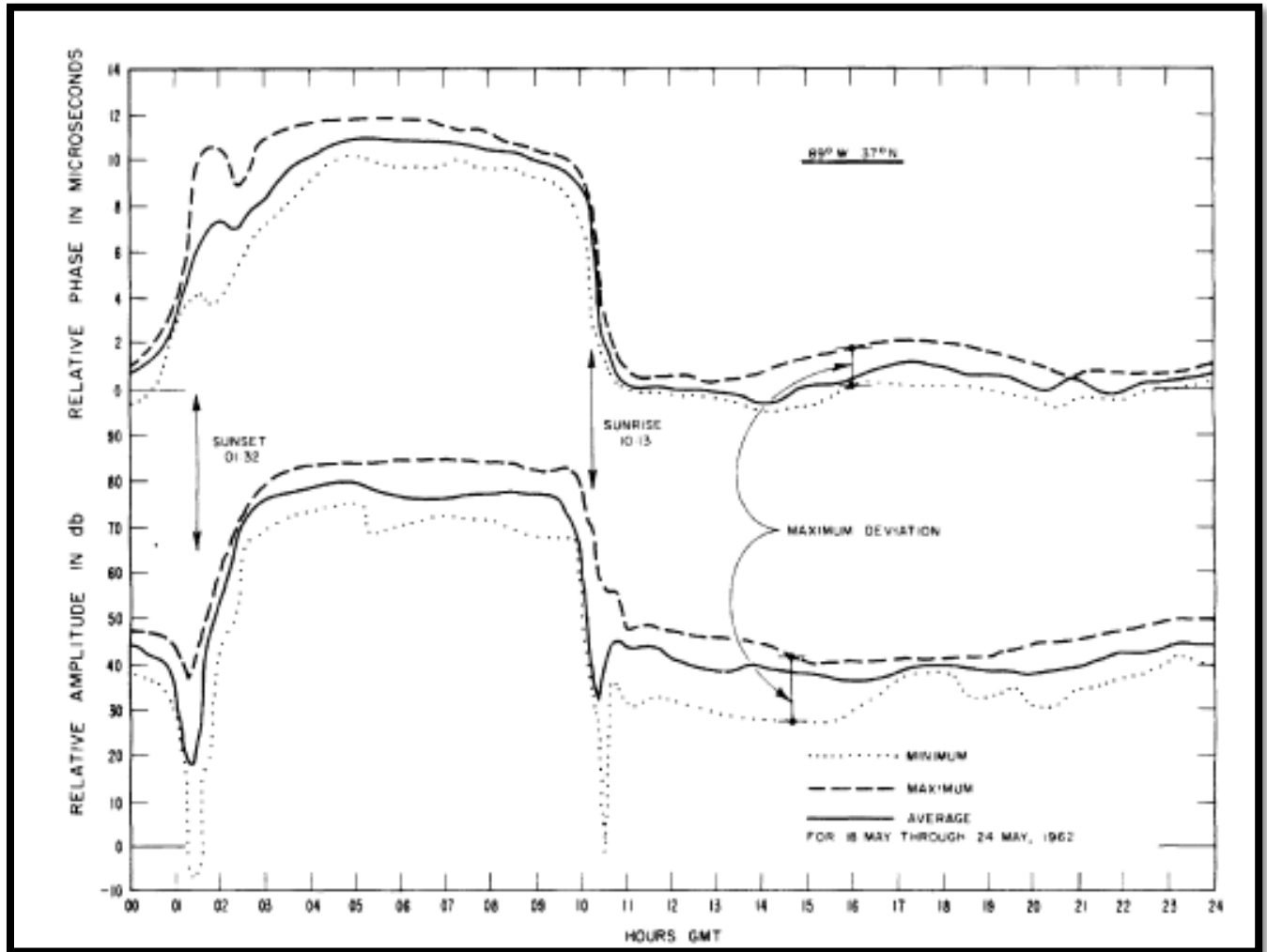


Figure 22. First-hop skywave from Carolina Beach Station, North Carolina to Boulder, Colorado, 1961. Source: Hefley, Gifford, *The Development of Loran-C Navigation and Timing*, U.S. Department of Commerce, October 1972, 117.

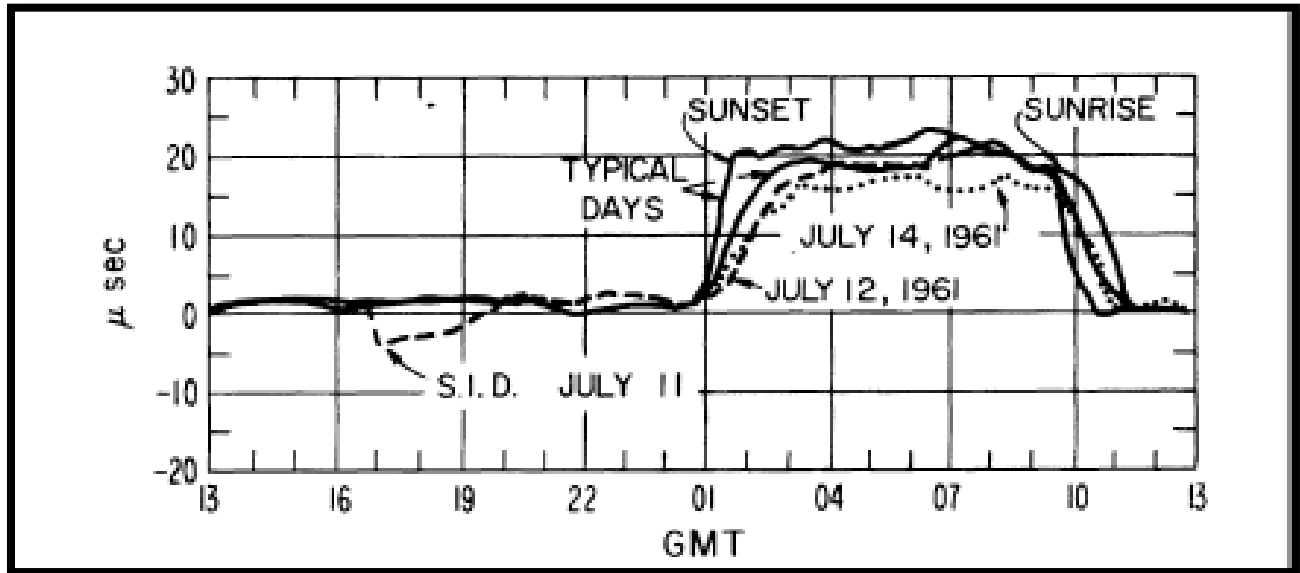


Figure 23. First-hop skywave from Carolina Beach Station, North Carolina to Boulder, Colorado, 1961. Source: Hefley, Gifford, *The Development of Loran-C Navigation and Timing*, U.S. Department of Commerce, October 1972, 118.

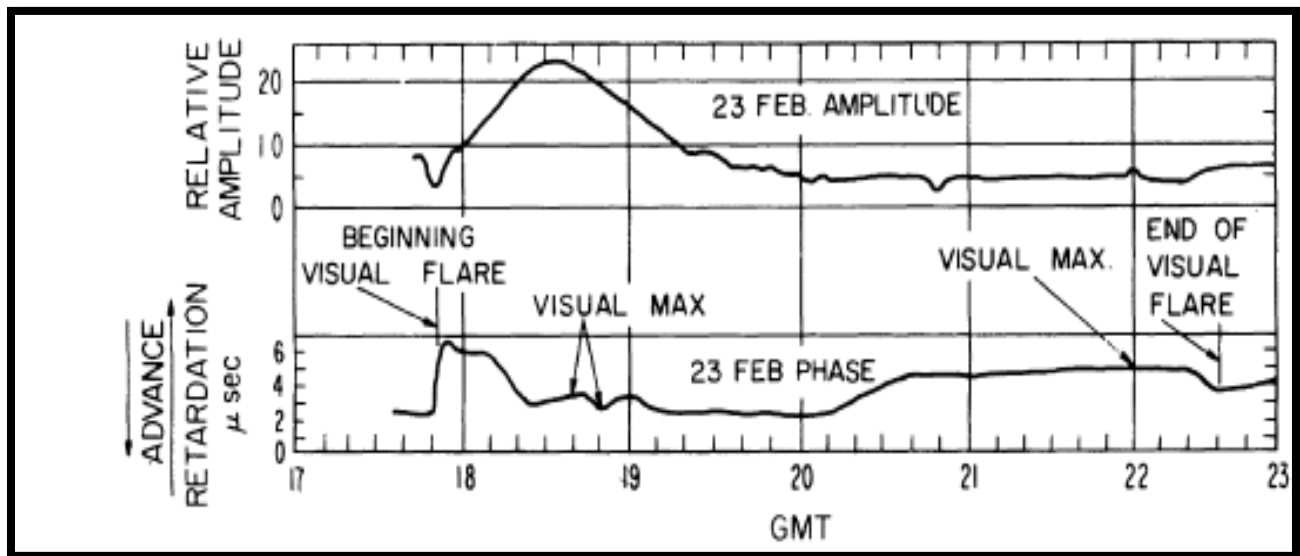


Figure 24. First-hop skywave from Carolina Beach Station, North Carolina to Boulder, Colorado, 1961. Source: Hefley, Gifford, *The Development of Loran-C Navigation and Timing*, U.S. Department of Commerce, October 1972, 118.

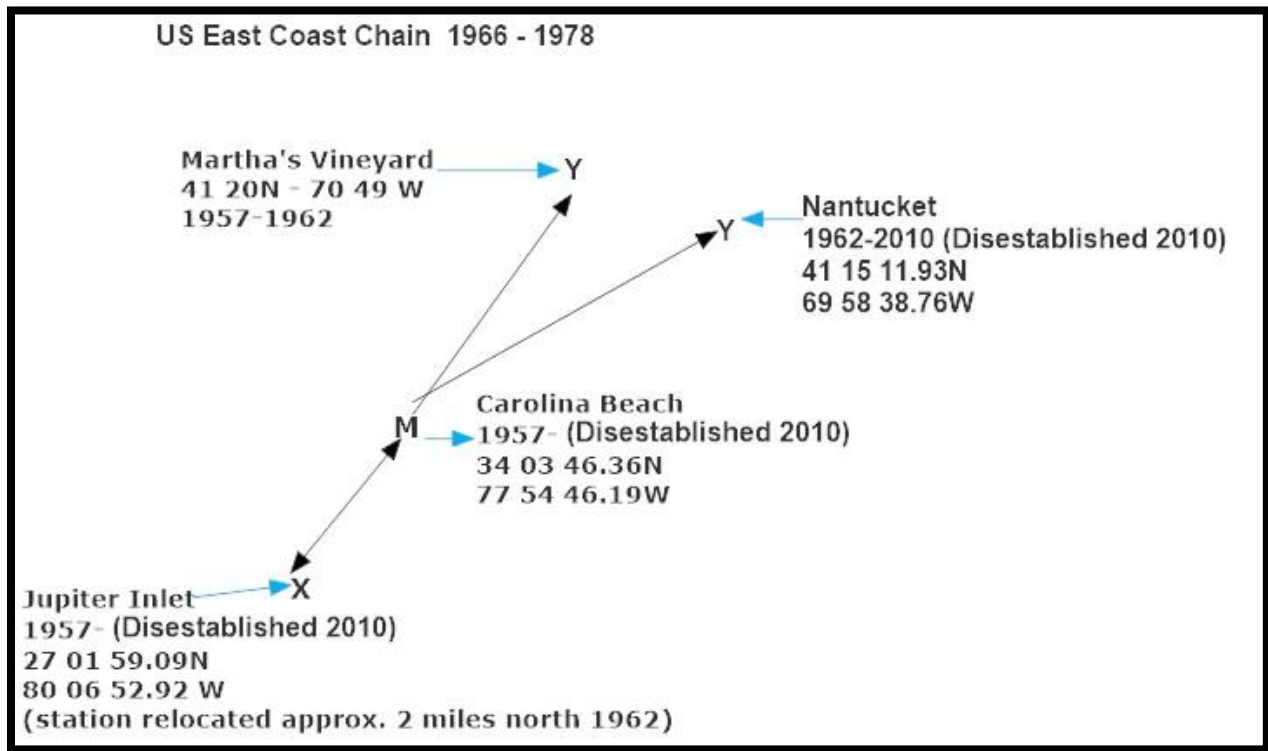


Figure 25. The US East Coast Chain 1957 – 1965

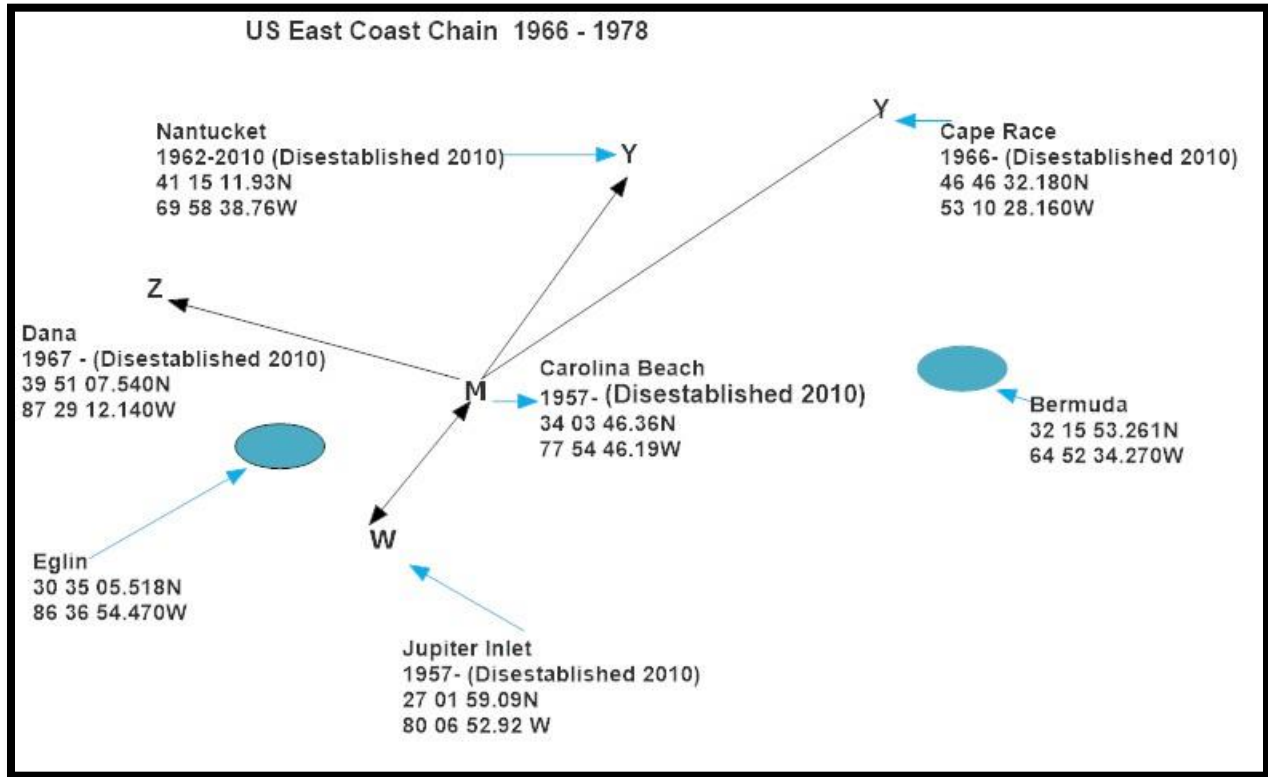


Figure 26 The US East Coast Chain 1966 – 1978

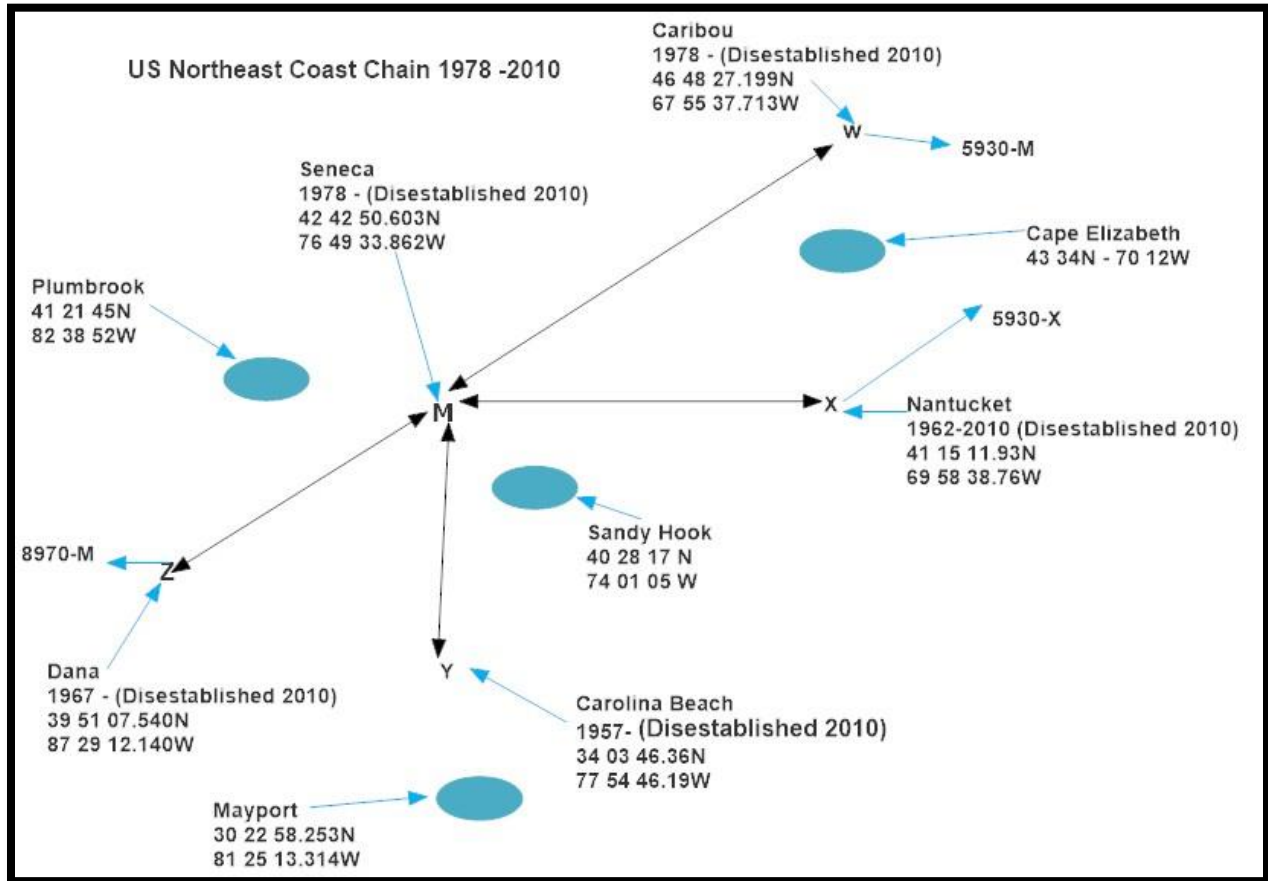


Figure 27. The US Northeast Coast Chain 1978 - 2010

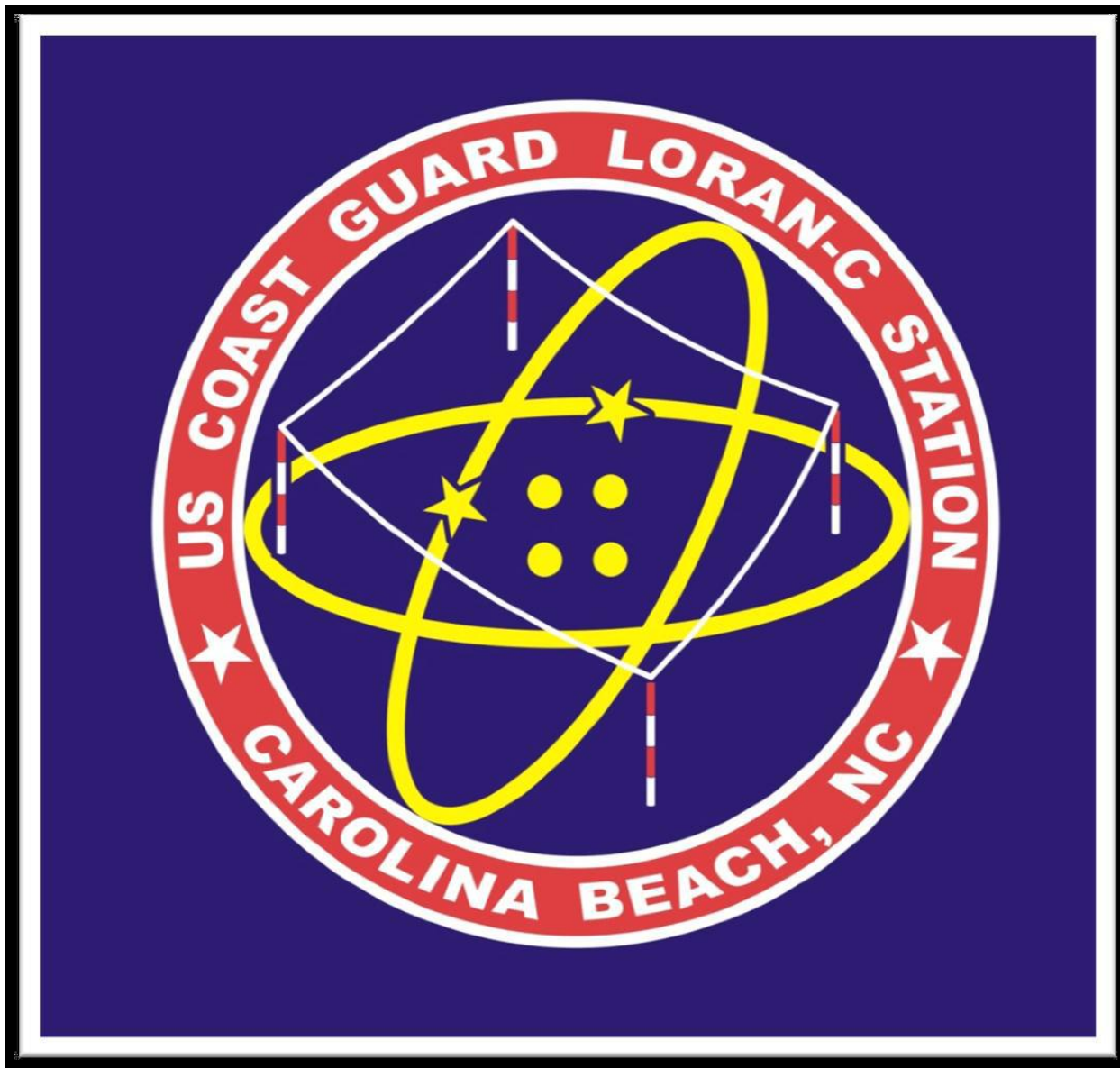


Figure 28. USCG Carolina Beach LORAN-C Patch.

DEMOLITION REPORT

UNITED STATES COAST GUARD
LORAN STATION CAROLINA BEACH, NORTH CAROLINA
LORAN-C TOWERS
STATION LETTER DESIGNATION: SO, SL-0, SS-0, SS-7, 9930 MASTER

Location: 9001 River Road, Wilmington, New Hanover County,
North Carolina

Date of Construction: 1967 (Loran-C Towers)

Engineers: United States Coast Guard (USCG)

Present Owner: United States Coast Guard (USCG)

Report Prepared by: Terri L. Foley, Historic Preservation Consultant
Shape Construction, Inc.
1234B Charleston Beach Rd, Ste 101
Bremerton, WA 98312

Previous Documentation on File: Historic America Engineering Record
Loran Station Carolina Beach, North Carolina
Loran-C Towers
Prepared by: Terri L. Foley, Shape Construction, Inc.
Location: North Carolina State Historic Preservation Office

Photographers: Terri L. Foley, Historic Preservation Consultant
Andrew S. Ludlow, Site Superintendent
Shape Construction, Inc.

Date: May 2014

PROJECT INFORMATION:

This Demolition report was undertaken in 2014 in accordance with the Architectural/Engineering Scope of Services 1 (1.1) (1.2) (1.3) (1.5) of the Memorandum of Agreement between the USCG and North Carolina State Historic Preservation Office (NC-SHPO). The four (4) Loran-C towers were dismantled and removed from the USCG LORAN Station due to the structural degradation, as well as surpassed functional life expectancy.

Site and Architectural Description:

The Carolina Beach LORAN-C station is located on a tract of land comprised of 210.76 acres and is enclosed by a three strand barb wire fence fronting approximately 3,030 feet on River Road.

The LORAN-C station transmitting antenna is a Top-loaded Inverted Pyramid (TIP), (see Figure 1) supported by four guyed 625-foot towers. The TIP is a multi-array configuration tower design used to transmit LORAN-C signals. The antennas are comprised of the wire arrays connected between the towers, and the towers serve as the anchors. Each antenna tower is a skeletal steel tower, supported with guy wires and the tower is electrically connected to the transmitter and therefore functions as the antenna for broadcasting the radio signal (see Figures 2, 3, 4). From each tower is a ground plane, a conducting surface that operates as part of the antenna to reflect the radiowaves from the other antenna elements. A ground plane comprised of an array of wires buried in the ground and radiate out from the base of the antenna.

Each tower is enclosed with by fencing with a communication hut located near the base of the tower. The towers sit on a concrete foundation. Guy wires are located at 150, 300, 450, and 600-feet on the tower and extend outward. Sidelights are located below the guy wires at the 150, 450, 600-foot level. The antenna cable and backstays are located at 600-foot and a beacon light is at the top of the tower. The antenna cable extends out to the TIP located on the transmitter building (see Site Plans and Engineer Plans, Figures 5, 6)

All towers were constructed at a cost of \$3,000.00 each in 1967. The transmitting antenna measures 3000' x 3000' x 600' (alumiweld cable) and was constructed in 1967 for a cost of \$3,000. The receiving antenna, fiberglass is 42' and cost \$2,000.00.¹

Scope of Work:

The controlled demolition LORAN-C towers (four) and the TIP antenna. Shape Construction, Inc. (SCI) acted as the On-Site Representative for this demolition.

¹ "Documentation of Proceedings of a Board Survey, Survey No. BS-32-001-90L," on file with the USCG Carolina Beach Loran-C station, Wilmington, NC.

Project Description:

SCI was awarded a contract by the USCG to provide on-site representation for the duration of the four (4), 625-foot skeletal steel, communications radio towers, the TIP antenna, enclosed tower fencing and communication huts located at the Carolina Beach LORAN-C station, North Carolina. Personal for the demolition project included an on-site superintendent, six tower demolition crew persons (3 tower crew and three ground crew) and one historic preservationist to conduct the recordation of the demolition process.

Reports:

Demolition Daily Reports were completed on-site, complete with digital photographs documenting the demolition activity. The daily reports outlined the day's events, times, as well as relevant background and site information.

Demolition:

The demolition of the four (4) LORAN-C towers, TIP antenna, enclosed fencing, and communication huts took place from April 14 to May 13, 2014, with site clean-up from May 13 – 15, 2014. Prior to the start of the project, SCI installed the appropriate signage to ensure that authorized personal were informed the site was under construction with instructions to wear the appropriate safety gear and to beware of the surroundings. Demolition for each of the four (4) towers required guy wires to be removed; prior to the removal of any guy wires extra temporary guy wires were added for stability for the duration of the dismantling of each tower. After the removal of each antenna from the first three towers, the demolition crew surveyed each tower to make any adjustments needed to realign each tower to stand straight with no leaning. Each tower is comprised of 25, 25-foot sections. The first 20 sections of each tower was removed by the tower demolition crew (3 persons) by the removal of bolts at the three bottom legs of each 25-foot section than lowered to the ground by a hoist. Each tower section was lowered in a controlled manner to the ground using a gin pole and hoist except for the last 125' which was lowered with a mobile crane. Once each section was on the ground, the ground crew (3 persons) relocated the sections to the dismantling station located off to the side of the tower. Two ground crew personal would dismantle the sections then place in a large dumpster with all cables to be recycled.

Narrative of the demolition of towers are in chronological order each tower was dismantled.

Tower 3 (April 14 – April 22): On the first day of operation, April 14, SCI conducted on-site set up, and photograph documentation of the existing site. Demolition of enclosed fencing for Tower 3 carried out on the first and second day. On April 15, setup for the removal of the antenna on Tower 3 was conducted. Due to high winds, the project was shut down on the afternoon of the second day (April 15). The antenna on Tower 3 was removed on April 16, with the TIP removed from the roof of the Transmitter building. The first section (top section) of Tower 3 was removed on April 16. A total of 20 sections were taken down from April 16 - 22, with the remaining five (5) sections to be removed as one piece by a crane on May 12.

Tower 1 (April 22 – April 28): Demolition of enclosed fencing was conducted April 22. Setup for demolition was completed on April 22. The antenna wire was lowered April 23, as well as the first few

sections. The completion of the dismantling of Tower 1 was completed (total of 20 sections) on April 28, with the exception of the last 125-feet (five sections) which were removed on May 12.

Tower 2 (April 28 – May 2): Demolition of enclosed fencing was conducted April 28. The setup for demolition was completed on April 28. The antenna wire was lowered April 29, as well as the first few sections. The completion of the dismantling of Tower 2 was completed (total of 20 sections) on May 2, with the exception of the last 125-feet (five sections) which were removed on May 12.

Tower 4 (May 2 – May 8): Demolition of enclosed fencing was conducted on May 2. The setup for demolition was completed on May 5, as well as the top or first section. The completion of the dismantling of Tower 4 was completed on May 8, with the exception of the last 125-feet (five sections) which were removed on May 12.

On May 12, the remaining four, 125-foot sections of each of the four towers were taken down by a crane. The dismantling of these four sections were conducted on May 12 and May 13. Site clean-up was conducted on May 13-15. The project was completed on May 15, 2014.





