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NAVY COLD WAR COMMUNICATION CONTEXT: RESOURCES ASSOCIATED WITH THE NAVY'S COMMUNICATION PROGRAM, 1946-1989

FINAL REPORT

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PREPARED FOR:

Atlantic Division
Naval Facilities Engineering Command
1510 Gilbert Street
Norfolk, Virginia 23511-2699

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EXECUTIVE SUMMARY

R. Christopher Goodwin and Associates, Inc. conducted these investigations between October 1995 and 1996 on behalf of the U.S. Department of the Navy, Atlantic Operations, Naval Facilities Engineering Command (NAVFACENGCOM). The Navy Cold War Communication Context was undertaken to develop a historical and thematic overview of the Navy's Cold War communication program between 1946 and 1989. The nation-wide context was prepared as a companion volume to the Legacy-funded Navy Cold War Guided Missile Context, and was designed to assist in identifying and evaluating the relative significance of Cold War built resources associated with the Navy's communication program. Development of a nation-wide context will allow the Navy to undertake assessments of Cold War-related built resources without conducting extensive investigations to develop an appropriate historic context or thematic framework. The historic context and comparative data presented in this study can be applied in the analysis of site-specific data.

The study presents comparative data on the various Navy installations and property types associated with the Navy's shore-based communication program during the Cold War. This included the development of a chronological overview of the Navy's role in communication activities, which spanned the period from World War I through the Cold War era. Major property types constructed to support the Navy's shore-based communication program also are addressed in this study. Resources that are less than 50 years old must meet the criteria of "exceptional importance" under the National Register of Historic Places (NRHP) to qualify for listing. Focusing on built resources constructed within the last 50 years serves as a proactive approach intended to assist cultural resource managers in making informed decisions about significant Cold War-era resources and to selectively preserve these resources before they are lost or indistinguishably altered.

The Navy Cold War Communication Context is organized into four major chapters: Introduction, Methodology, The U.S. Navy's Role in the Cold War Communication Program, 1946-1989, and Property Types Associated with the Navy's Shore-Based Communication Program. Chapter I provides an overview of the project and research objectives. The methodology section (Chapter II) discusses the scope of the archival and field investigations, and analysis of data. Chapter III presents a chronological overview of the Navy's role in the Cold War communication program. This includes an examination of technological developments associated with Navy communication systems. The section on property types (Chapter IV) identifies the types of properties that were constructed specifically to support the Navy's communication program.

Appendices were developed to supplement the narrative text. Appendix A, Navy Installations Associated with the Navy's Cold War Communication Program, provides a summary of the various Navy installations that were directly involved in the Navy's communication program during the Cold War. Appendix B, The U.S. Navy's Cold War Communication Systems, contains a more comprehensive list of shore-based communication systems developed for the Navy. Appendix C contains a list of the U.S. Navy's active ship force levels between 1946 and 1989. Appendix D contains a technical glossary and a key to abbreviations. Appendix E contains resumes of key project personnel.

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CHAPTER I

INTRODUCTION

Overview of Project

The Navy Cold War Communication Context was undertaken to develop a national historic context for the Navy's Cold War communication program between 1946 and 1989, and was designed to serve as a companion volume to the Legacy-funded Navy Cold War Guided Missile Context. The Navy Cold War Communication Context provides a chronological overview of the Navy's communications activities, which examines the technological developments of the Navy's shore-based communications systems and identifies the principal installations involved in the Navy's communications efforts. The study also examines the property types associated with the Navy's Cold War communication program, such as transmitter stations, receiver stations, high frequency direction finder (HF/DF) stations, and the various antenna types.

The development of a nation-wide context provides the historic and thematic perspective for assessing the relative significance of built resources associated with the Navy's Cold War communications activities. Information presented in this study can be used to assist cultural resource managers in evaluating these resources and developing preservation goals and priorities.

R. Christopher Goodwin and Associates, Inc. conducted these investigations between October 1995 and 1996 on behalf of the U.S. Department of the Navy, Atlantic Operations, Naval Facilities Engineering Command (NAVFACENGCOM). The objective of this study was to provide a broad framework examining the historical and thematic context and property types associated with the Navy's Cold War communication program. All work was undertaken in accordance with the guidelines set forth in the Secretary of Interior Standards for Historic Preservation, and current Department of Defense (DoD) guidance regarding the evaluation of Cold War-era resources.

Research Objectives

The main objective of the Navy Cold War Communication Context was to assist the Department of the Navy in executing its responsibilities under Section 110 of the National Historic Preservation Act (NHPA) of 1966, as amended. Resources that are less than fifty years old must meet the criteria of "exceptional importance" under the National Register Criteria for Evaluation (36 CFR Part 60.4) to qualify for listing. Focusing on built resources constructed within the last fifty years serves as a proactive approach intended to assist cultural resource managers in making informed decisions about the relative significance of Cold War-era resources, and to selectively preserve important Cold War resources before they are lost or indistinguishably altered. This objective was achieved through the following tasks:

- development of a chronological overview of the Navy's role in shore-based communication activities during the Cold War;
- examination of the principal Navy bases and/or facilities involved in the Navy's shore-based communication program; and
- examination of relevant property types associated with the Navy's shore-based communication program.

This single source provides comparative data on the various Navy installations and property types associated with the Navy communication program This study will assist in conducting assessments of Cold War-related resources within their appropriate historic context The study is not, however, intended to replace installation-specific resource investigations; instead, it provides comparative data that enables the analysis of site-specific information within an appropriate nation-wide context. Historic contexts, as defined in the National Register guidelines developed by the National Park Service (NPS), "are those patterns, themes, or trends in history by which a specific occurrence, property, or site is understood and its meaning (and ultimately its significance) within prehistory or history is made clear" 1 Historic contexts are the cornerstones of cultural resource identification, evaluation, and management activities.

Previous Investigations

Studies dealing with Cold War-era resources are limited to date. A number of archival projects have been undertaken to document various aspects of the Cold War. One project, conducted by the Woodrow Wilson International Center for Scholars, Washington, D.C., presents a compilation of perspectives on the history of the Cold War from previously classified documents. Cornell University has been involved in a project to collect Vietnam-related artifacts. Another project, sponsored by the State Department, was designed to collect Eisenhower-related material culture.

The Center for Air Force History published a report in June 1994 entitled Coming in from the Cold: Military Heritage in the Cold War. The report summarized the efforts of the Department of Defense (DoD) Legacy Cold War Task Force in response to a Congressional mandate to "inventory, protect, and conserve" Cold War-era resources. The task force represents one of the major study groups established under DoD's Legacy Resource Management Program. The publication, American Forces in Berlin 1945-1994: Cold War Outpost (1994), was prepared by Robert P. Grathwol and Donita M. Moorhus as one of the Cold War projects. The publication presents a historical overview of the role of American forces in Central Europe throughout the Cold War period.

In 1994, the U.S. Air Force developed preliminary guidance for evaluating and treating Cold War resources under their control. These guidelines, entitled "Interim Guidance Treatment of Cold War Historic Properties for U.S. Air Force Installations", rely on a thematic approach and state that only those resources of national significance are eligible for listing in the National Register. The guidelines further state that resources of regional or local significance should be assessed as they approach the 50-year age criteria.

More recently, nation-wide studies were undertaken for both the Navy and Army/Air Force Cold War guided missile program. The Navy component was prepared by R. Christopher Goodwin and Associates, Inc., and the Army/Air Force component was prepared by the U.S. Construction Engineering Research Laboratories (USACERL). USACERL also is in the process of preparing a nation-wide study on Army/Air Force radar sites associated with the Cold War communication program.

Several installation-specific studies that address the theme of Navy communications also have been completed. These include cultural resource investigations at the Naval Security Group Activity (NSGA) Sabana Seca, Puerto Rico; NSGA Northwest, Virginia; Naval Radio Transmitter Facility (NRTF) Driver, Virginia; and, Naval Air Station (NAS) Keflavik, Iceland. These investigations were undertaken by R. Christopher Goodwin and Associates, Inc. on behalf of the Department of the Navy in partial fulfillment of Section 110 requirements of NHPA. Information compiled from these investigations was incorporated into the Navy Cold War Communication Context.

Research into the Cold War era is on-going. A major obstacle to these investigations is the volume of classified data. However, as previously classified information becomes accessible to the public, more comprehensive information on the Navy's communication program and other Cold War topics will become available

CHAPTER II

METHODOLOGY

Archival Research

The following tasks were undertaken to fulfill the objectives of this study: archival research, field investigation, data synthesis, and report preparation. Data were collected and analyzed to provide a narrative discussion of the evolution of the Navy's Cold War communication program between 1946 and 1989, and to identify property types directly associated with the Navy's program.

The Navy Cold War Communication Context required an analysis of the patterns of the U.S. Navy's involvement in communications development and technology during the Cold War. This analysis is intended to enable the reader to understand how individual installations fit into the broader historical pattern. A thematic context was developed that examined the evolving roles and missions of the various Navy installations involved in the Navy's Cold War communication efforts. This context was organized into defined chronological periods in order to provide a temporal framework for the development of the Navy's communication program. The Secretary of the Interior's Standards for Preservation Planning and the guidelines set forth in the National Register of Historic Places provided the framework for developing this context.

Research began with a review of general histories on Navy communications, such as Linwood Howeth's History of Communications Electronics in the United States Navy (1963) and Louis Gebhard's Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory (1979). These sources were instrumental in providing a comprehensive understanding on the Navy's involvement in the communications field during the period preceding the Cold War.

The next step in the research process was to link the evolution of the Navy's communication program to the physical development of individual Navy installations. Primary and secondary sources were reviewed as part of this research process. Primary sources included the Command Histories of individual Naval installations on file at the Operational Archives of the Naval Historical Center, Washington Navy Yard. Command Histories were prepared on a yearly basis and provide insightful information on an installation's activities and physical development.

Archival research undertaken for this study was conducted primarily at the Library of Congress, Washington, DC, and at the Operational Archives of the Naval Historical Center at the Washington Navy Yard, Washington, DC. Other repositories consulted included the National Archives, Washington, DC; Naval Institute, Annapolis, Maryland; the Navy Department Library, Washington Navy Yard; and the Historical Electronics Museum in Baltimore, Maryland. Site-specific information also was obtained from the various Navy installations visited during the course of this study.

Field Investigations

Representative Navy installations associated with the Navy's communication program were visited as part of these investigations. These field investigations were designed to accomplish two primary objectives: (1) to collect written and graphic documentation and (2) to develop property typologies for built resources associated with the Navy's communication program.

A field investigation of Naval Security Group Activity (NSGA) Winter Harbor, Maine, was conducted specifically for the current investigation. Field findings from other projects undertaken for NAVFACENGCOM were used to provide comparative data for both the thematic context and property types section of the report. These included the Naval Security Group Activity (NSGA) Sabana Seca, Puerto Rico; NSGA Northwest, Virginia; Naval Radio Transmitter Facility (NRTF) Annapolis, Maryland; NRTF Driver, Virginia; NRTF Isabela, Puerto Rico; Naval Low Frequency Transmitter Facility (NLFTF), Aguada, Puerto Rico; High Frequency (HF) Receiver Facility, Salinas, Puerto Rico; and Naval Air Station (NAS) Keflavik, Iceland. Information compiled from these architectural surveys (i.e., field survey forms, photographic documentation, and construction drawings) was incorporated into this study. A case-study approach was used to highlight specific installations.

Data Synthesis

Data collected during archival and architectural investigations were correlated, analyzed, and synthesized in accordance with the organizational framework established in the research design. The research design for the Navy Cold War Communication Context integrates the three components of an historic context -- time period, geographic area, and theme -- with associated property types. This approach establishes the connections between major themes in the history of the Navy during the Cold War and real property. The context was designed to assist in future assessments of the relative significance of individual properties and historic districts under the Department of the Navy's stewardship.

The thematic context that was developed as part of this study provides a chronological overview of the Navy's role in military communications during its initial development and subsequent Cold War expansion. The Navy Cold War Guided Missile Context should be referenced for a general historical overview of the U.S. Navy during the Cold War.

A discussion of property types associated with the Navy's communications program was derived from information gathered during both archival research and site investigations. The analysis of property types was a two-step process. Archival research was undertaken to identify the range of anticipated property types associated with the Navy's Cold War communication program. Analysis of photographs, construction drawings, and other graphic documentation provided insight into the range of property types, character defining features, and trends in design. Archival work was followed by field investigations to Navy installations to verify these anticipated property types.

Organization of the Report

This study is designed to serve as a management document, which provides cultural resource managers with the data necessary to identify and evaluate significant built resources constructed to support the Navy's Cold War communication program. The report is not intended to present a comprehensive history of military communications technology or provide a complete inventory of the Navy's real property associated with this theme. Rather, it is intended to provide guidance for installation-based investigations by providing comparable data on major properties identified within the overall development of the Navy's communication program during the Cold War. The report is intended to assist in identification and evaluation efforts. Identification includes the development of historic property inventories for Cold War-related resources. Evaluation includes recognizing those resources of exceptional significance, according to the National Register criteria, and recognizing major property types directly associated with the Navy's communication program.

The Navy Cold War Communication Context is organized into four major parts:

- Chapter I - Introduction
- Chapter II - Methodology

- •Chapter III - The U.S. Navy's Role in the Cold War Communication Program, 1946-1989
- •Chapter IV - Property Types Associated with the Navy's Shore-Based Communication Program

Chapters I and II provide background information on the project, including the research objectives, types of archival and architectural investigations, and data analysis. Chapter I provides an overview of the project and research objectives. Chapter II presents the methodology and organization of the report. This chapter includes a discussion of the scope of the archival and field investigations, and analysis of data.

Chapter III, The U.S. Navy's Role in the Cold War Communication Program, 1946-1989, presents a chronological overview of the Navy's role in the Cold War communication activities. The chapter presents an overview of the initial establishment of the Navy's communication program during the early-twentieth century and later development during the Cold War. The chapter is organized into defined chronological periods that correspond to major periods of U.S. history. Organization of the historic context according to chronological periods allows the reader to reference portions that are relevant to their site-specific research.

Chapter IV, Property Types Associated with the Navy's Shore-Based Communication Program, provides an overview of the types of properties that were constructed specifically to support the Navy's communication program. This chapter is divided into two general sections: shore-based communication facilities and shore-based communication and surveillance systems. These general categories are further subdivided to identify the major property types within each category. For example, built resources associated with the Navy's communication facilities include operations buildings, transmitter and receiver buildings, and helix houses. This chapter presents a summary of the evolution and function of the property type; a description of character defining features; and, a discussion of the property type's role within the communication program.

The appendices were developed to supplement the narrative text. Appendix A, Navy Installations Associated with the Navy's Cold War Communication Program, provides a summary of the various Navy installations that were directly involved in the Navy's communication program during the Cold War. These summaries highlight the installation's period of significance and provide a brief background on their involvement. Appendix B, The U.S. Navy's Cold War Communication Systems, contains a more comprehensive list of shore-based communication systems developed for the Navy. The communication systems are organized according to function, including radar systems, direction finder (D/F) systems, low frequency (LF) systems, etc. This list provides an overview of each system's period of use, technological developments, and brief description. Appendix C, U.S. Navy Active Ship Force Levels, 1946 - 1989, contains a table of the types and numbers of vessels the U.S. Navy had in operation throughout the Cold War period. A brief summary of historical highlights is included for each decade; this serves to tie the increases and/or decreaes in vessel count to broader historical trends. Appendix D contains a technical glossary and a key to abbreviations. Appendix E contains resumes of key project personnel.

CHAPTER III

THE U.S. NAVY'S ROLE IN THE COLD WAR COMMUNICATION PROGRAM, 1946-1989

Introduction

The thematic history of the Cold War communication program was developed to provide a chronological overview of significant events, trends, and technological developments associated with the Navy's communications systems from the early beginnings of radio-electronics to more recent developments. The parameters of this study were to develop a thematic context for the Navy's shore-based communication program, and to identify major property types associated with this mission. Development of a thematic context provides an appropriate overview within which to assess built resources associated with the Navy's communications program.

Over the past century, communications has played an important role in military operations. Naval communications includes all personnel, facilities, and equipment engaged in conducting rapid communications for the Navy. Rapid communications encompasses encrypting and decrypting; routing; reproduction; distribution; and record-keeping.2 Naval communications relies on reliable, secure, and rapid transmission and receipt of information. With the introduction of radio during the early-twentieth century, the Navy found an effective way to maintain direct communication between its shore commands and ships at sea. As the twentieth century progressed and radio technology evolved, the Navy constantly upgraded its equipment and refined its techniques. The Navy's network of communications facilities is used as the primary means of communicating between shore stations, ships, submarines, and aircraft.

Early Wireless Communications: 1900-1920

The first successful demonstration of the telegraph over a long distance came in 1843, when Samuel B. Morse wired his famous message "What hath God wrought?" from Washington to Baltimore. Although its usefulness was limited to locations near telegraph lines, the telegraph provided instantaneous communication over vast distances. By the close of the nineteenth century, scientists had begun to speculate that light was but one form of electro-magnetic radiation, and that other forms of radiation exhibited many of the characteristics of light. In 1864, James Clerk Maxwell postulated that electro-magnetic energy travels through space in the form of invisible waves, which traveled at the speed of light. Heinrich Rudolph Hertz validated Maxwell's theories in 1888 by transmitting electro-magnetic waves (or radio waves) across a room.3

During the latter 1890s, the Italian inventor Guglielmo Marconi recognized the commercial potential of these theories. Marconi experimented with transmitting electro-magnetic waves, or radio waves, for the development of a telegraph system. By 1895, Marconi succeeded in transmitting a signal for a distance of three miles. On 12 December 1901, Marconi received a transmission at his Newfoundland Station from a transmitter in England. During the years that followed Marconi's first demonstrations, both continuous improvements in the technology, and bitter quarrels among inventors and interested parties characterized the history of wireless communications. Marconi, an Italian, was living in Britain. The British government, which had a monopoly on telegraph service, fought Marconi's commercial applications. Other inventors sought to improve Marconi's equipment and, as a result, hundreds of patents were granted during this period.4

Navy's Early Interest in Wireless Technology

Promoters of wireless technology considered the U.S. Navy one of their most important potential customers, and in later years, the Navy claimed considerable credit for nurturing the infant industry. During this period, the Navy represented the primary funding source for communications research. The Navy also encouraged internal research as well as funded civilian contractors in developing new technologies and apparatus. The Navy commenced testing wireless apparatus in 1899. During that year, the first official radio message was sent from ship to shore. Radio stations were established in Washington, DC, and at the Naval Academy in Annapolis, Maryland, to conduct tests for various equipment. During this same year, the U.S. Navy established a Wireless Division in the Bureau of Equipment and an electrical and radio school at the New York Navy Yard for radio instruction. From 1902 onward, the Navy was a significant market for the new invention.5

This new technology, however, was not accepted universally when it was first introduced. Many commanders were not willing to dedicate time, funding, or manpower to the new technology. The reluctance to accept radio communications was due, in large part, to the fact that these early wireless systems were primitive and unreliable, and were often vulnerable to enemy detection. These early systems utilized poor tuning techniques, and receivers often did not pick up transmitted signals. In addition, these systems broadcast on such a wide spectrum that their signals were detected easily. As a result, the enemy could listen to messages for intelligence value, or could jam messages with their own signals.6 As the technology of radio communications improved, its use within the Navy expanded.

President Roosevelt placed the Navy in charge of government radio operations, at which time the Bureau of Equipment began expanding the shore system to meet the challenge. By 1902, additional naval shore stations were established at Cape Elizabeth, Maine; Cape Anne and Boston, Massachusetts; Newport, Rhode Island; Montauk, New York; Navesink, New Jersey; and, Cape Henlopen, Delaware. Each station was equipped with a Slaby-Arco 60 cycle spark transmitter set, which was capable of a maximum transmission distance of approximately 137 miles. These shore stations were placed at considerable distances to reduce interference in transmitting radio messages. The U.S. Naval Radio Laboratory in Great Lakes, Illinois, served as a relay point for messages transmitted between Washington, DC, and the West coast. By 1904, the Navy established nineteen shore radio stations.7

When the "Great White Fleet" set sail around the world in 1907, its ships were equipped with radio telephones purchased from the DeForest Radio Telephone Company. The radio telephone system utilized a version of the Poulson arc for the transmitters and combined crystal and triode detectors for the receivers. Naval personnel, however, were not properly trained in operating the new systems and the test proved a failure.8 Many sets were disassembled and stowed as soon as the fleet set sail. This experience did, however, prompt the Navy to develop its own radio research laboratory in 1908, the U.S. Navy Radio Laboratory. The laboratory was the site for experiments with vacuum tubes and other radio components that made voice transmissions possible.9

By the second decade of the twentieth century, radio communications within the Navy steadily improved. Part of the credit for these improvements goes to S.C. Hooper, who became the communications officer of the Atlantic Fleet in 1912. Hooper succeeded in imposing discipline and standard procedures for radio operators, who previously worked without supervision. Hooper also instituted competitions among ships for efficient communications. Many of the training programs instituted by Hooper proved their value, as radio communication became more reliable and received increased support from senior officers.10

Establishing a Chain of High-Powered Communication Stations

By 1908, the Navy had established a chain of radio stations that was capable of relaying messages between the Atlantic and Pacific coasts. In 1911, a transmitting station was established at Arlington, Virginia, on land acquired from the War Department at Ft. Myer "Radio Virginia" , better known as NAA Arlington, served as the Navy's central radio station for communication from the Navy Department to Fleet Commanders and provided coverage of the North Atlantic and continental U.S. Initial construction of this facility included a 600-foot tower; two 450-foot towers; and, a transmitter and receiver building. These towers, which were nicknamed the "Three Sisters", were the highest radio towers built at that time. A Fessenden 100-kw synchronous rotary spark transmitter and a 35-kw Federal arc transmitter were installed prior to the end of 1912. This station represented the Navy's first high-power transmitter, and was placed into service on 13 February 1913.11

Additional shore radio stations were constructed by the Navy to provide rapid communication between Alaska and the Aleutians, and Seattle, Washington. In the spring of 1911, three temporary stations were established in Alaska at Kodiak, Dutch Harbor, and St Paul. Additional Alaska stations were established at Unalga, St. George, and Cordova. All of these stations were equipped with the latest quenched-gap transmitters capable of maintaining communications with stations on the Pacific coast at night utilizing frequencies between 165 and 300 kc.12

In August 1912, Congress appropriated $400,000 to construct a chain of high-powered communications stations along the Atlantic and Pacific coasts, including Panama. The authorization act contained the following provision:

> Toward the purchase and preparation of necessary sites, purchase and erection of towers and buildings, and the purchase and installation of machinery and apparatus of high-power radio stations (cost not to exceed one million dollars).13

The act further stipulated that stations should be located in the following areas: the Canal Zone, California, Hawaii, American Samoa, Guam, and the Philippines. Construction of the Canal Zone site, which was situated in Darien, was initiated in December 1913 by the Quartermaster Department of the Panama Canal. All buildings were constructed of concrete; the arc and receiving rooms were completely shielded by grounded wire mesh imbedded in the concrete. Three 600-foot steel towers were erected to support the different sections of a flat-top antenna. The Canal Zone station employed a 100-kw arc transmitter, and was supplemented by a Navy-designed heterodyne receiver. Plans for the other high-powered stations were similar to the basic layout of the Canal Zone site, however, changes were made to accommodate the natural terrain of each area. The high-powered receiver station at Chollas Heights, San Diego, was the first to be completed. Commissioned in May 1917, the new transmitter, which was designed to complement a lower powered station located at Point Loma, was the most powerful radio transmitter in North America. The Chollas Heights station was equipped with a 200-kw arc transmitter, which provided a reliable radio link between Arlington, Virginia, and Pearl Harbor, Hawaii.14 The radio station at Pearl Harbor became operational in October 1919 and the radio station at Cavite, Philippines, was opened in December 1919. Due to the success of the Darien site, it was decided to equip both Pearl Harbor and Cavite with 350-kw arc transmitters. These transmitters were capable of communicating directly between the two stations, thus eliminating the need to relay messages through Samoa and Guam.15

Research and Development (R&D) Efforts During World War I

With the commencement of World War I, the Navy sought to develop new equipment for secure communications, interception techniques, and cryptanalysis in response to the increased requirements for signals security and signals intelligence (SIGINT). By the time that the United States entered the war, research and development (R&D) activities in this country had almost ceased. This situation forced the Navy into design and manufacture. At the same time, new manufacturers entered the field and sources became available that permitted the Navy facilities to refocus their attention on R&D activities.16

The Navy established a Radio Test Shop at the Washington Navy Yard for the purpose of designing naval receiving equipment and testing the equipment of commercial manufacturers. Several small temporary laboratories were established to conduct studies on proposed antenna systems. The Naval Aircraft Radio Laboratory also was founded during this period, and was responsible for conducting research into improvements for aircraft radio communications.17

One of the most important advancements in radio communication technology during World War I was the improvements made in the design and manufacture of vacuum tubes. Earlier tubes were too fragile for military use and, as a result, great efforts were directed towards developing a dependable and uniform vacuum tube suitable for military application.18 The De Forest Company produced improved tubes for both the U.S. Army Signal Corps and the Navy. Western Electric and General Electric also manufactured large quantities of tubes for the Army. At the same time, researchers at Bell Laboratories conducted experiments with the electronic high-vacuum tube; this technology was first introduced in the intercontinental telephone links.19

Expansion of the Navy's Communication Network During World War I

When the United States entered World War I, President Woodrow Wilson directed the Navy Department to assume responsibility for the establishment and operation of a transatlantic communication system with headquarters at Belmar, New Jersey. This transatlantic communications link enabled Washington to communicate with ships at sea, as well as with its Allies through stations at Canarvon, England; Lyons and Nates, France; Stravanger, Norway; and, Rome, Italy. In addition, the station could monitor radio transmissions from inside Germany. This system comprised facilities taken over by the Navy from commercial interests, principally the Marconi Wireless Telegraph Company. The facilities included transmitting stations located at New Brunswick and Tuckerton, New Jersey, and, Sayville, New York; and receiving stations at Belmar, New Jersey; Chatham, Massachusetts; and, Bar Harbor, Maine.20

The transmitting stations were responsible for broadcasting orders to the fleet, including naval ships at sea and U.S. merchant ships. The station at New Brunswick, New Jersey, was largely completed when the Navy assumed control of its operations. This facility was constructed by the Marconi Company and was fitted initially with a 350-kw Marconi time-sparked transmitter. The New Brunswick station became the world's most powerful transmitting station with the installation of a 200-kw alternator, and was the first high-powered station on the Atlantic coast able to transmit radio messages continuously and reliably. Navy ships in all parts of the world were able to communicate with the New Brunswick station. It was later utilized for radiotelephonic communication with the U.S.S. George Washington during President Wilson's trips to and from France during the peace conference.21

The high-powered station at Tuckerton, New Jersey, was taken over in September 1914. The Navy upgraded the Tuckerton station with the installation of a 100-kw arc transmitter. The Navy took control of the Sayville, New York, station in July 1915. The Sayville station had been constructed and operated by the Atlantic Communication Company in conjunction with a sister station at Nauen, Germany. During 1917, the Sayville station was used for transatlantic work when conditions permitted. During the early part of 1918, the facility was upgraded with the installation of a 200-kw arc transmitter which increased the reliability of transatlantic transmissions.22

The receiving station at Bar Harbor, Maine, was located at Otter Cliffs on Mount Desert Island. The site possessed "phenomenal" receiving range and became the Navy's chief transatlantic receiving center for the remainder of the war. The operations area consisted of a communications receiving building, a direction-finding (D/F) building, and two 210-foot steel radio towers.23

In October 1917, a contract was awarded for the construction of a radio station at Cayey, Puerto Rico. The Navy established other stations, including Colon, Canal Zone, and San Francisco, California. These latter radio stations were designed using standardized designs developed by the Bureau of Yards and Docks, and employed arc transmitters. Also during this period, the Navy recognized the need to establish a high-powered radio transmitting station in France and a similar one in the southern United States to provide continuous duplex radio communication between the two countries.24 The Navy selected Annapolis, Maryland, across the Severn River from the Naval Academy as the site for the U.S. radio transmitting station (Figure 1). Construction of the Naval Radio Transmitter Facility (NRTF) Annapolis commenced immediately and included the erection of a four-sided, flat-top antenna. Each side was 400 feet long and supported by four, 500-foot towers. A 500-kw transmitter was installed to support this antenna system. The Annapolis station was placed in service in September 1918 using two 500-kw Poulson Arc Converter VLF transmitters built by Federal Telegraph Company of San Francisco under a contract from the Bureau of Steam Engineering. The Annapolis radio station operated as a low-frequency (LF) communications link between the U.S. and Europe during World War I.25 "At the time of its completion the Annapolis station was the most powerful one in the United States, with the exception of the one at New Brunswick, N.J., and was one of the most powerful in the world".26

In July 1916, the Naval Radio Service was abolished and the Naval Communication Service, administered by the Chief of Naval Operations (CNO), was established in its place. The Naval Communication Service was charged with providing efficient communication services to the fleet. The Shore Station section of Naval Communications was responsible for procuring, administering, and operating the shore communication system. The Naval Communication Service followed the same organization of the recently established naval district system, with all stations within a district transmitting their traffic to the district's central station. Messages were then relayed via the various district central stations to its final destination.27

With the U.S. entry into the war, the Naval Communication Service began operating a network of low-frequency radio direction finder (D/F) stations on the Atlantic and Pacific coasts. D/F equipment was installed around the seaward approaches to the strategic harbor of Brest, France. The equipment was utilized to determine enemy submarine positions for the purposes of taking offensive action and rerouting convoys to safer entry courses. Throughout the war, additional D/F stations were constructed along the harbors of Boston, New York, and Charleston, and at the entrances of the Delaware River and the Chesapeake Bay. Their successful operation resulted in the establishment of additional D/F sites at important ports in the United States, on the Great Lakes, and at dangerous navigational points along the coast.28

Throughout World War I, thousands of personnel were trained to provide the manpower necessary to operate these newly-established radio stations. To meet these requirements, the Navy activated hundreds of personnel in Communications Reserves and established radio schools in each naval district to provide preliminary training. Two schools were established for advanced training, one on the east coast at Harvard University and the other on the west coast at Mare Island, California. By the end of 1917, almost 5,000 students were enrolled in the four-month intensive radio program. By early 1918, this number had quadrupled.29

The Electronic Age and Depression Years: 1920s-1930s

World War I saw great advances in the arena of radio communication. The period between World War I and World War II, known as the "electronic age", marked the beginning of the radio broadcast industry and industrial research in electronics. By the end of the 1920s, radio had evolved into the "broadcast boom". From the perspective of the Navy, this period marked the development of a comprehensive and reliable radio communication system. By the end of this decade, Naval radio stations were equipped with the best available equipment in the world.30

The advent of broadcasting resulted in the rapid development of broadcast stations, particularly near large population centers along the coast. These new stations, which utilized the same frequency spectrum as the Navy, caused interference with signals at the Navy receiver stations. The increased use of radio necessitated strong Federal radio control, which eventually led to the formation of the Federal Communications Commission (FCC). This body assumed the licensing function of the Department of Commerce and was responsible for controlling internal radio policy. Naval personnel adjusted to the increased use of the air waves by avoiding commercial broadcast frequencies. This, in turn, prompted Navy research personnel to focus on experimenting with the higher frequency ranges 31

Post War Organization of the Naval Shore System

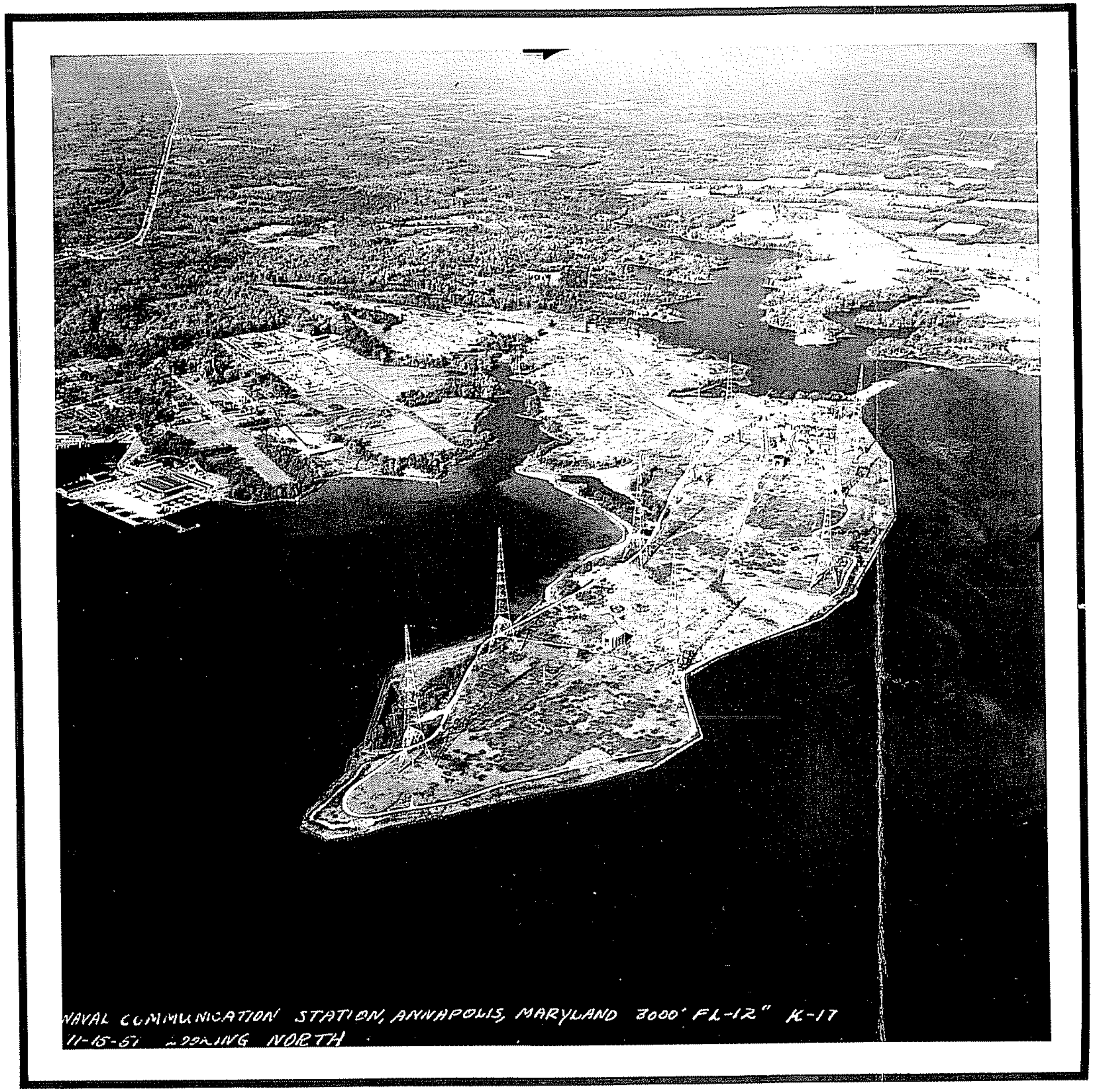
Following World War I, the naval shore radio system was revamped. Naval shore stations were divided into three categories in accordance with assigned missions and included (1) high-powered stations; (2) medium-powered stations; and (3) low-powered stations. High-powered stations included those capable of transmitting at least 3,000 miles and were located at strategic points in the U.S. These stations were intended for transmitting messages to fleet units by broadcasting, and were equipped with arc equipment. Medium-powered stations were those capable of transmitting at least 1,000 miles and were used to connect adjacent naval districts and provide long-distance ship-to-shore service. These stations were equipped with medium-powered arc equipment. Low-powered stations provided transmission ranges of less than 1,000 miles and were situated along the coast to provide close-in ship-shore service and communications with the naval district headquarters. These stations were equipped with low-powered arc equipment or spark transmitters. All stations were connected to their own district centers by landline or radio.32

During the 1920s, the Navy took the first steps toward systemizing its cryptoanalytic programs with the establishment of a Research Desk in the Intelligence Department's Codes and Signals Section. The Security Section of the Naval Communication Service was established and was responsible for the creation of codes and ciphers for the Navy; monitoring and cryptanalyzing radio communications; and communication intelligence.33 In order to train cryptanalytic personnel, a series of intercept stations were established by the Navy. The first station was established at Guam in 1925, followed by two stations in the Philippines and another in Shanghai. Additional intercept stations were established in the U.S. at Bainbridge Island, Washington; Winter Harbor, Maine; Jupiter, Florida; Cheltenham, Maryland; and abroad in Corregidor, Philippines, and Aiea, Oahu.34 It was soon clear that the number of trained personnel was inadequate, and the Navy initiated a program to train selected candidates. The training facility was located at the old Navy Department building in Washington, DC. By World War II, over 176 men had graduated from the program. These graduates formed the core of the Navy's SIGINT effort.35

Upgrading the Navy's Radio Stations

During the mid-1930s, many of the early arc transmitters at navy radio stations were upgraded. In 1931, the first superheterodyne receivers were installed in the fleet. In 1937, the original 500-kw Poulson Arc Converter VLF transmitters at NRTF Annapolis were taken out of service and replaced by the model TBJ 500-kw transmitter. The model TBJ transmitter, which was designed by General Electric, employed vacuum tube technology that proved more effective and less susceptible to interference than the earlier generation of arc transmitters.36

In 1935, the Navy initiated construction of a radio station on Big Moose Island in Maine. The facility included 210-foot "Eiffel" towers, two receiver antennas, and an antenna field of rhombic antennas. An operations building (Building 3) served as the communications center.37



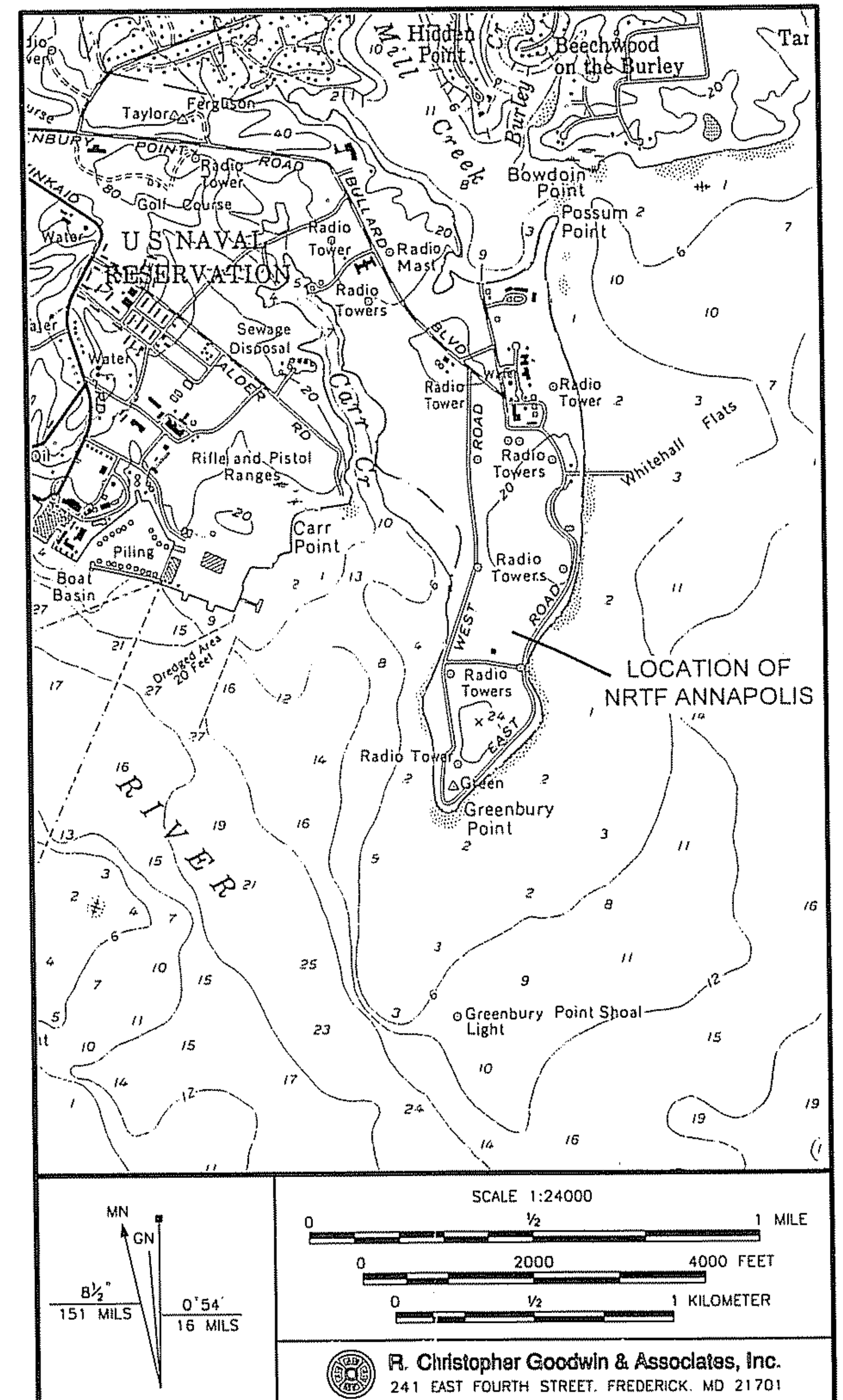


Figure 1 Aerial photograph of Naval Communication Center at Annapolis, Maryland, November 15, 1951 (Courtesy of the National Archives and Records Administration, Still Photo Branch) and portion of USGS Annapolis Quadrangle map showing installation location

Post War R&D Activities

Rapid demobilization following World War I severely restricted work at the Radio Test Shop at the Washington Navy Yard and at other Navy yards. The Philadelphia Navy Yard devoted its efforts to improving direction finding apparatus The Naval Aircraft Radio Laboratory conducted studies in multiple transmission and reception, and increasing the radio frequency spectrum 38

The Radio Test Shop continued its earlier R&D work with vacuum tube transmitters. During the war, significant advancements had been made in vacuum tube development, including increased ruggedness and longer life span. However, few advances were made in increasing power output. In January 1920, the Bureau of Engineering held the first of a series of conferences with representatives from various electronics firms to stimulate interest in developing higher power tubes. This conference marked the turning point in tube development. In early 1921, intensive research was initiated by both General Electric and Western Electric, under Navy guidance and financial assistance. By 1922, significant improvements were made and high radio frequencies capable of matching those of the arc were achieved; the vacuum tube soon supplanted the arc transmitter. In July 1922, General Electric supplied the Radio Corporation of America (RCA) with its newly-developed 20-kw tubes for installation at the RCA commercial radio station in Long Island. These improved vacuum tubes were purchased first by the Navy in 1924 and installed at their Arlington, Virginia, transmitter station.39

In 1923, the Navy established the Naval Research Laboratory (NRL) at Anacostia, DC, to serve as its principal in-house research laboratory for radio communications and scientific research into special projects for the Navy. Activities conducted at the Naval Aircraft Radio Laboratory, the Radio Test Shop, and the Naval Radio Laboratory were consolidated under NRL. Dr. A. Hoyt Taylor was appointed division superintendent and Dr. J.M. Miller was assistant superintendent.40

Between 1925 and 1929, the Navy relied on its own R&D efforts for the development of radio and electronic equipment. During the period, fifteen different models for shore stations and shipboard HF transmitters were procured by the Navy. Equipment designed by NRL personnel was manufactured by a handful of private companies, including General Electric, Westinghouse, and the Radio Corporation of America (RCA). One of the initial tasks assigned to NRL was research into higher radio frequencies in response to the increasing interference problems from commercial radio stations. To accomplish this, NRL personnel designed a transmitter to operate within a frequency range between 1,500 and 2,500 kc. In early 1925, the Navy conducted successful tests in higher frequency transmission between the fleet in New Zealand, Australia, and Washington, DC.41

Work also was initiated on radar development, with much of this research conducted in secret. Interest in radar was prompted by military needs for better surveillance and navigational aids, as well as weapon control. Military interest in radar was sparked when two researchers at the Naval Aircraft Radio Laboratory, A. Hoyt Taylor and Leo C. Young, noted distortions in received signals during experiments conducted in 1922. Taylor and Young noted that some radio signals were reflected from vessels passing on the Potomac River and discovered that ranges and bearings of the vessels could be calculated from the reflected signals. This observation marked the discovery of radar.42

Radar (Radio Detection and Ranging), a term coined by the U.S. Navy, operates by radiating electromagnetic energy and analyzing the presence and character of echo returned from reflecting objects. Range, or distance, of an object is determined by the time it takes to transmit a radio pulse and receive that pulse. Simply stated, if the transmitted signal bounces back, an object has been detected. These reflected signals were displayed on a cathode-ray-tube (CRT) screen, which was deciphered by an operator. The main advantages of radar were the detection of a target at great distances and the ability to locate its position with relatively high accuracy.43

The period of of National economic depression was characterized by limited R&D activity by either the military or commercial interests. Sales of commercial equipment declined rapidly as unemployment rose which, in turn, forced many smaller manufacturers to close their businesses. Drastic reductions in military appropriations resulted in severely curtailed Navy research activities and a decline in personnel support. Experimentation continued on a much smaller scale and was limited to the areas of radar, sonar, limited-range voice radio equipment, and radio-controlled aircraft.44

In March 1934, NRL commenced work on the development of pulse radar in cooperation with the Carnegie Institution. The pulse transmitter was used to study the ionosphere by measuring ionospheric heights. The following year, the Naval Appropriations allotted $100,000 towards this research effort. By the late 1930s, NRL had installed the first complete radar antenna, "Topsy", at one of its buildings in Anacostia. The radar system consisted of a "directable" antenna that rotated for a 360-degree coverage.45

Although the economic situation in the U.S. improved by the mid-1930s, events overseas caused growing concern. Hitler's political victories in Germany forced the U.S. to accelerate military mobilization and to place increased emphasis on R&D activities.46

Naval Communications During World War II: 1940-1945

Between 1925 and the outbreak of World War II, the development of communication equipment had been primarily confined to the spectrum between 15 kc and 30 mc. During World War II, communications frequencies moved into the microwave range, and vacuum tube technology became inadequate as a result. Developments in communications technology throughout the war were marked by great strides in the development of electronics applications Fleet Admiral E.J. King, CNO, stated in a report to the Secretary of the Navy in December 1945:

Perhaps the greatest technological advances of the entire war have been made in the field of electronics, both within the naval laboratories and in collaboration with the Office of Scientific Research and Development.47

Throughout World War II tremendous pressure was put on manufacturers to develop equipment for military communications. For example, Bell Laboratories devoted roughly 80 per cent of its efforts to military applications. As a result of the accelerated R&D efforts, new methods were developed for ship and airborne search, fire control systems, and accurate long-range navigation. Another significant result of World War II was the greater role of electronic warfare (EW), including the development of countermeasures for jamming enemy radar and communication systems.48

Developments in Radar Technology

The exploitation of radar arose from military needs during World War II. Radar offered an effective solution for accurately detecting and locating aircraft, ships, and other targets. Before the invention of radar, airborne objects were located by radiogoniometry, or "direction finding", using angular bearings. This method required plotting the angles on a map of relative bearings to locate an object. The major disadvantage of this system was that it was limited to locating "friendly" targets, or those sending out an active signal.49

In October 1939, prior to the U.S. entry into World War II, the government awarded RCA a contract for the production of six airborne radar units. In August 1940, Rear Admiral Bowen persuaded the General Electric Company to establish a radar production plant. By October of that year, Bowen also convinced Westinghouse executives to join the war effort. Bell Laboratories was another major player in radar development. Radars designed by Bell Laboratories and produced by Western Electric were used in ground, air, and ship-based systems. Bell Laboratories also established a "School for War Training", which trained thousands of officers in the use of communications and weapons systems. In October 1940, the Radiation Laboratory, nicknamed the "Rad Lab", was established at the Massachusetts Institute of Technology (MIT). The Navy established its own unit for radar design, procurement, installation, maintenance, and training. This radar unit continued to function as a separate entity until late 1942.50

Early radar systems proved their usefulness throughout the war. Warning radar was used in the Battle of the Coral Sea to detect Japanese attack formations at a range of 70 miles. Radar also was used successfully to detect enemy submarines in the Atlantic shipping lanes. By 1941, the Navy had established radar stations at Guam, Midway, Johnson, Palmyra, Samoa, Wake Island, Guantanamo, and Tutuila.51

By the end of the war, a total of $3,719,000,000 had been spent on radar development.52 This intensive research effort resulted in many advancements in radar technology, such as the "klystron", an ultra-high frequency microwave tube, which was used in radar and aircraft guidance. Other developments included the cathode ray tube (CRT), microwaves, television, transistors, and timing circuits. Advancements in radar technology were translated into many important civilian applications, particularly navigation for ships and aircraft. Most of the basic radar techniques developed during the war provided the basis for modern radar development.53

Naval Intelligence Efforts

Prior to World War II, strategic intelligence was minimal in the United States military. In addition, the small group of intelligence personnel established by that date were reluctant to share information or coordinate intelligence gathering efforts. World War II, however, resulted in the rapid expansion of the intelligence system and increased cooperation among the military branches. The first civilian SIGINT operation, the Office of Strategic Services (OSS), was created. A new branch of the War Department also was established to evaluate enemy decrypts. Known at first as the Signal Security Division, the new group employed 28 officers and 55 civilians. At the end of 1942, the agency established its headquarters at Arlington Hall in Virginia, across the Potomac River from Washington, DC. A major intercept base was constructed to support the agency's activities at Vint Hill Farm outside Warrenton, Virginia.54

As the Naval cryptoanalytic effort expanded and the services needed new quarters to house the increased personnel. In the summer of 1942, it relocated to Mount Vernon Academy, a finishing school for girls located on Nebraska Avenue in northwest Washington. At the same time, the cryptanalytic unit in Washington, as well as its outposts in the Pacific, were transferred from the Office of Naval Intelligence to the Office of Naval Communication.55

Expansion of the Navy's Communication Network

On the eve of World War II, the Navy's radio communication system encompassed a global chain of high-, medium-, and low-frequency transmitting stations, receiving stations, and supplementary stations. The Bureau of Yards and Docks' construction program for radio stations in the continental United States was modest - allocations for buildings and structures totalled $25,000,000. Additional funds, however, were allocated for new equipment under the Bureau of Ships. These funds were used to improve existing east and west coast facilities, including Mare Island, San Diego, Skaggs Island, Annapolis, Cheltenham, and Norfolk.56

The Annapolis station was upgraded as part of this program through the installation of 50 kw LF transmitters. The number of radio transmitters in operation at Annapolis almost tripled during the war. In 1941 a total of 19 transmitters were operating; by 1945, this number increased to 50. By the early 1940s, the radio station at Annapolis was established as the "primary transmitting station for communication command and control with deployed units" and operated one of the highest-powered transmitters in the world.57 Throughout the war, all radio messages transmitted by the Navy Department, Washington, DC to fleets at sea and overseas naval bases were sent through this station. The station's longest regular circuit throughout the war was between Annapolis and Pearl Harbor; messages for ships and stations beyond this point were relayed by the Navy's Oahu station.58

The largest project undertaken during this period was the construction of a communications annex at Washington, DC. A number of new radio stations also were established, including Bainbridge Island, Washington State; Dupont, South Carolina; New River, North Carolina; Quantico, Virginia; Quonset Point, Rhode Island; Squantum, Massachusetts; Point Isabel, Texas; Chatham, Massachusetts; Jupiter, Florida; Alameda, California; and, Castroville, California. These high-powered stations employed the broadcast method to send messages to ships in the Atlantic and Mediterranean. By using this method, the ships were not required to reply to each message, and possibly reveal their locations to the enemy.59

A major emphasis during this period was placed on expanding overseas radio facilities at Hawaii, Alaska, and other advanced bases. The Naval Operating Base (NOB) at Adak, Alaska operated as the main ship-to-shore and point-to-point station, handling traffic within the sector and with the U.S. mainland.60 In 1943, China and the United States established the Sino-American Cooperative Organization (SACO) which established weather, communications, and intelligence stations at sites from Indo-China to the Gobi Desert. These stations assisted the American submarine campaign, as well as provided critical information to the 14th Air Force.61

Other activities during World War II included the expansion of the Navy's network of high frequency D/F stations along the Atlantic and Pacific coasts. By World War II, the chain of D/F stations extended from Iceland to the middle of South America. During the war, the Navy's shore and ship D/F systems played an important role in defeating the German submarine menace.62

Reorganization of the Naval Communication Program

The Navy responded to the expanding role of naval communications by reorganizing the Naval Communications Service in early 1942. A separate section was established to accommodate the growing Communication Intelligence (COMINT) field. Other newly-created sections included frequency coordination and control (Op-20-Y); liaison with Allies (Op-20-I); supervision of traffic and communication procedure (Op-20-T); and, cryptographic research (Op-20-N). By 1944, the Director of Naval Communications was responsible for overseeing activities in the following sections: administration; shore; electronics; fleet; communication intelligence; communications security; naval postal affairs; cryptographic research; plans and operations; registered publications; countermeasures; cryptographic aids; and, aeronautics.63

At the height of World War II, more than 22,000 officers and 225,000 enlisted men composed the Naval communication program. Approximately 140,000 enlisted personnel were trained specialists assigned to duty as radiomen, radio technicians, aviation radiomen, and aviation radio technicians.64

Truman and Eisenhower Years: 1946-1960

The substantial military force built during World War II faced major reductions immediately following the war. The United States had raised an armed force of 12 million during the course of the war; by 1947, this number had been reduced by 90 per cent. Soon after the end of World War II, however, it became increasingly apparent that the Soviet Union was pursuing policies in conflict with American ideals and interests. In response, the United States embarked on a policy to contain Communist expansionism. The United States provided Greece and Turkey with military aid in 1947, and a year later launched the Marshall Plan to revive the depressed economies of Western Europe.65 In 1949, the United States joined the nations of Western Europe in a military alliance against Soviet aggression as a member of the North Atlantic Treaty Organization (NATO) American priorities shifted to the NATO alliance and to the defense of Western Europe.

As part of U.S. diplomatic policy during the Cold War, the Navy maintained control at sea. During the 1950s, the Soviet Union began to rebuild its navy, concentrating on submarines and naval aircraft. Reductions in the British Navy lead to the U.S. Navy to patrol areas previously monitored by the British navy. During the Korean (1950-1953) and Vietnam (1963-1973) conflicts, the Navy provided vital support to embattled ground forces through carrier-based aviation, naval gunfire, amphibious landings, coastal patrols, and supply blockades.

In addition to the Korean and Vietnam conflicts, the Navy also supported a variety of international commitments. The Navy protected North Atlantic shipping lanes to Europe and patrolled the Mediterranean for the North Atlantic Treaty Organization (NATO). The Navy also supported U.S. commitments to defend non-communist nations of the western Pacific.

Establishment of the Intelligence Community

Following World War II, the signals intelligence force was faced with major reductions in personnel and funding. The OSS, established during World War II, was abolished by President Truman and its activities were divided between the State Department and the armed services. With the onset of the Cold War, however, the nature of the military intelligence mission was changed substantially. The major focus was directed toward monitoring Soviet military activity in areas close to U.S. and Russian borders. For the first time in its history, the United States decided to make intelligence a peacetime priority.66 Before the war, the intelligence community consisted of a small network of personnel. Most U.S. intelligence dealt strictly with military affairs and was generated by the armed services, including the Office of Naval Intelligence (ONI) and the Division for Military Intelligence. Their efforts focused on collecting information about the numbers and capabilities of weapons deployed by foreign countries. Neither office had a large staff, nor did they have a unit dedicated to analysis.67

As conditions leading to the Cold War developed, the President realized the value of a strong, centralized intelligence community. In March 1945, the Army-Navy Communications Intelligence Board was established in an effort to coordinate activities between the two branches. In January 1946, Truman established the Central Intelligence Group (CIG) to assume this function. CIG was composed of State, Army, and Navy personnel. The State Department established its own office, known as the Bureau of Intelligence and Research (INR), to handle cryptologic intelligence. In 1947, President Truman signed the National Security Act, which created the Central Intelligence Agency (CIA); the CIA was the successor to the World War II-era OSS. The Director of the CIA was provided direct access to the President and the National Security Council. This expanded group of intelligence organizations functioned as a clearinghouse for information, as opposed to consolidating the communications intelligence community.68

The intelligence community quickly grew to encompass numerous military and civilian organizations, including the National Security Agency (NSA); the Energy Research and Development Administration (ERDA); the Federal Bureau of Investigation (FBI); and, the Treasury Department.69 The National Security Agency (NSA) was established in 1952 by secret Executive Order to coordinate communications intelligence, including codes, ciphers, and electronic listening devices. NSA is the largest organization responsible for collecting intelligence. Signals Intelligence (SIGINT), whose role was to discover enemy capabilities and intentions, became the responsibility of NSA.70 SIGINT encompasses traffic analysis, direction finding, call-sign research, and other highly specialized skills. The smallest of NSA's three operating divisions is the Office of Communications Security (COMSEC), which is responsible for the protection of secret American government communications.71 NSA acquires raw intelligence from two parallel intercept sources: the listening posts located around the world that are under NSA's direct control and those listening posts operated by the three military branches

(U.S. Army Intelligence and Security Command, the U.S. Naval Group and the U.S. Air Force Electronic Security Command). All of these facilities filter unprocessed signals to NSA's headquarters in Fort Meade, Maryland. NSA's operations, personnel, and budget remain largely secret.72

Expansion of the Military's Surveillance Network

By the 1950s, the U.S. military had established an extensive surveillance system and collection network that consisted of ground stations, aircraft, ships, and submarines. The land-based air defense network consisted of a number of interlocking systems that protected both the United States and Canada against ballistic missile and aircraft attacks across the Arctic. The United States and Canada jointly built three radar screens known as the "DEW Line" (Distant Early Warning), the "Mid-Canada Line", and the "Pinetree". The DEW Line, which was completed in 1957, was operated by the Air Force to detect manned bombers and air-breathing missiles. It consisted of a chain of radar stations located 500 miles apart along the North American continent. These stations contained administrative and communications offices, living quarters, storage facilities, and a large radome that protected the radar equipment. A tropospheric scatter microwave radio system, nicknamed "White Alice", linked the Alaskan and DEW Line stations with command headquarters. Information collected at these stations was relayed to the North American Air Defense (NORAD) Command's Combat Operations Center near Colorado Springs, Colorado.73

During the late 1950s, construction was initiated on a multi-billion dollar Ballistic Missile Early Warning System (BMEWS) that extended across the Far North. The BMEWS system consisted of a small chain of very large radars for the detection of enemy ballistic missile attack on North America from the general direction of the Soviet Union. Both RCA and Bell Laboratories were involved in developing the BMEWS communications network. Three sites were established at Thule, Greenland; Clear, Alaska; and Flyingdales, England. Information obtained at these sites was transferred, via a computer network, to NORAD's Combat Operations Center. Starting in 1961, the BMEWS sites have provided support to the USAF SPACETRACK program in tracking orbiting satellites.74

The Navy established its own radar detection and tracking stations across the southern United States that were operated by Space Surveillance (SPASUR). Receiving stations were located at Fort Stewart and Hawkinsville, Georgia; Hollandale, Mississippi; Truth & Consequences, New Mexico; and Chula Vista, California. Transmitting stations were established at Wetumpka, Alabama; Marricipa, Arizona; and Olney, Texas. The transmitters emitted a vertical beam of continuous wave (CW) radio energy in east-west and north-south directions that illuminated a satellite. The reflected energy was transmitted back to a receiver, which receives the information and transmits it to SPASUR headquarters in Dahlgren, Virginia, for analysis.75

Formation of the Naval Communication System

In 1950, the CNO officially established the "Naval Communication System". By this date, the Navy's shore communications program consisted of two main elements: (1) the communications departments of shore activities and (2) the Naval Communication System. Shore activity communication departments were responsible primarily for local communications, while the Naval Communication System was responsible for inter-area and intra-area communications. The shore activity communication departments were composed of communication centers at naval bases, air stations, ammunition depots, and supply depots. Many of these facilities also played support roles, such as fleet and air operational support. These departments provided a link with the worldwide network of the Naval Communication System.76

The Naval Communication System, which was established in 1950 as the "backbone" of naval communications, was an integrated network for rapid communication service on a worldwide scale for the Navy. Under the direction of the CNO, this system was responsible for providing the means of transmission for CNO directives and instructions to the principal fleet, area, and force commanders, and for the collection of intelligence from these commanders 77

The Naval Communication System consisted of a network of primary, secondary, and inactive stations (Figure 2). Six naval communication stations or facilities were designated as primary communication centers, including Washington, DC; San Francisco, California; Pearl Harbor, Hawaii; Guam; Balboa, Canal Zone; and, Port Lyautey, French Morocco (Figure 3). The primary communication stations furnished complete radio coverage over the strategic ocean areas.78

Five types of activities were included in the Naval Communication System: (1) Naval Communication Stations (NAVCOMMSTA); (2) Registered Publication Issuing Offices (RPIO's); (3) Fleet Post Offices (FPO's); (4) Naval Communication Units; and (5) Naval Security Group. The NAVCOMMSTA's played a major role in the overall operation of the Naval Communication System. A NAVCOMMSTA included all communication facilities and ancillary equipment that were required to provide essential communication services for a specific area. All NAVCOMMSTA facilities performed the following tasks: (1) teletypewriter tape relay functions; (2) radio transmitting and receiving facilities for a communication center; and, (3) primary, secondary, or limited fleet support facilities. In addition, most NAVCOMMSTA's provided communication support for Naval Districts or River Command commandants, the commanders of naval bases, stations, or shipyards, and Marine Corps commanders.79

Figure 4 presents the organization of a typical NAVCOMMSTA which is divided into six departments: administration, personnel, communications, supply and fiscal, security group, and maintenance. The communications department represents the largest department, accounting for roughly 75 per cent of the station's personnel. Radio, traffic, material, and facilities comprised the four divisions of the communications department. A typical NAVCOMMSTA included a communication center (COMMCEN) that contained a message center, a cryptographic center, and transmitting and receiving facilities. The COMMCEN was responsible for receipt, transmission, and delivery of messages. The communication center could consolidate these functions at a single location or divide transmitting and receiving facilities from the communication center.80 A naval radio station (NAVRADSTA) was responsible for performing radio transmitting, receiving, or link relay functions at a location geographically distant from the COMMCEN. A type-designating letter (T or R) is added in parentheses to indicate the functions (transmitting or receiving) that a radio station performs.81

Although much of the work of the Naval Communication System was accomplished by the NAVCOMMSTA's, important functions also were performed by the Naval Communication Units (NAVCOMMU's) and the security group departments. The security group departments were responsible primarily for special communication functions, and consisted of four branches (direction finder, supplementary, security activity, and registered publications). The NAVCOMMU's were established to perform limited support and/or special communication functions at locations outside the United States. Typically, these activities were located at remote locations. A total of fifteen NAVCOMMUs were established by the early 1950s.82

Continued R&D Efforts

Starting in the late 1940s, new types of antenna structures were developed in response to technological advancements. One important invention was the transistor, which became available in the late 1940s, and led to significant improvements in military communications equipment.

During the 1950s, NRL continued to serve as the Navy's primary R&D facility. In 1951, NRL discovered that radar pulses beamed to the moon were reflected back to earth from a relatively small central spot on the moon's surface. This discovery proved the feasibility of using "moon bounce" for communications. Initial experimentation soon led to further testing, including MOONBOUNCE, which used the moon as a passive reflector. By 1954, the Navy had transmitted the first continuous wave (CW) traffic over a moon reflection circuit. The following year, the first moon relay circuit was established between Washington, DC, and San Diego, California. This circuit, which carried single channel radio-teletypewriter transmissions, proved the feasibility of long distance communications between two earth terminals using the moon as a passive reflector.83 A Communication Moon Relay (CMR) system was installed at NRTF Annapolis in 1959, which served as the transmitter site; a receiver site was constructed at Cheltenham, Maryland.84

In 1958, the Navy marked another important milestone in communications when meteor burst communication techniques for ship-to-shore communications were found feasible. The first message using this technology was transmitted from the U.S.S. Tulare to the Naval Electronics Laboratory in San Diego, California, over a distance of roughly 600 nautical miles (nm). The technique utilized ionized trails produced by meteors as a reflecting medium for very high frequency (VHF) transmissions. These transmissions were not seriously impacted by ionospheric disturbances, and were relatively safe from interception and jamming.85

Expansion of the Navy's Shore Facilities

During the late-1940s, the Navy's communications planners recognized the need for a very high power, very low frequency (VLF) radio transmitter to broadcast to the North Atlantic and Arctic. Radio waves transmitted at LF or VLF can travel past the curvature of the earth, bounce off the atmosphere, and return to earth, where they can be picked up. Radio Jim Creek was established in Snohomish County, Washington, in 1953 to fulfill this need. The Navy's "Big Jim", as it was known, represented the world's most powerful radio transmitter. It was designed for an output in excess of one million watts and capable of providing reliable, high power VLF broadcasts to Navy fleets far at sea. The Jim Creek facility consisted of twelve, 200-foot steel towers constructed along 3,000 feet of mountain ridges, which supported the giant antenna system.86

Starting in the early 1950s, the Navy undertook a major construction program at naval communications stations worldwide to accommodate its expanding role. Secondary fleet and general broadcast stations were established at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.87

In 1953, the Bureau of Yards and Docks issued a publication to aid all personnel in the design and construction of radio communication facilities. The general design policy promulgated in the publication was as follows:

Because uninterrupted communications must be maintained, particularly in emergencies, it is the policy of the Bureau to design communication facilities that are functional to the highest degree; this requires construction that is of permanent type, and blast- and splinter-resistant whenever possible. Masonry and/or reinforced concrete construction is generally used, the end results being windowless buildings with mechanical ventilation or air conditioning.88

The U.S. Naval Communication Station Norfolk is a case in point. Following World War II, the radio station at Naval Base Norfolk no longer could accommodate the increased communication traffic of the Commander in Chief, U.S. Atlantic Fleet and the Supreme Allied Commander Atlantic. The high-noise levels and absorption factors in the naval base area, as well as limited space prompted the relocation of transmitting and receiving facilities. Building Z-86 was constructed in 1947 at Naval Base Norfolk to serve as the U.S. Navy Communication

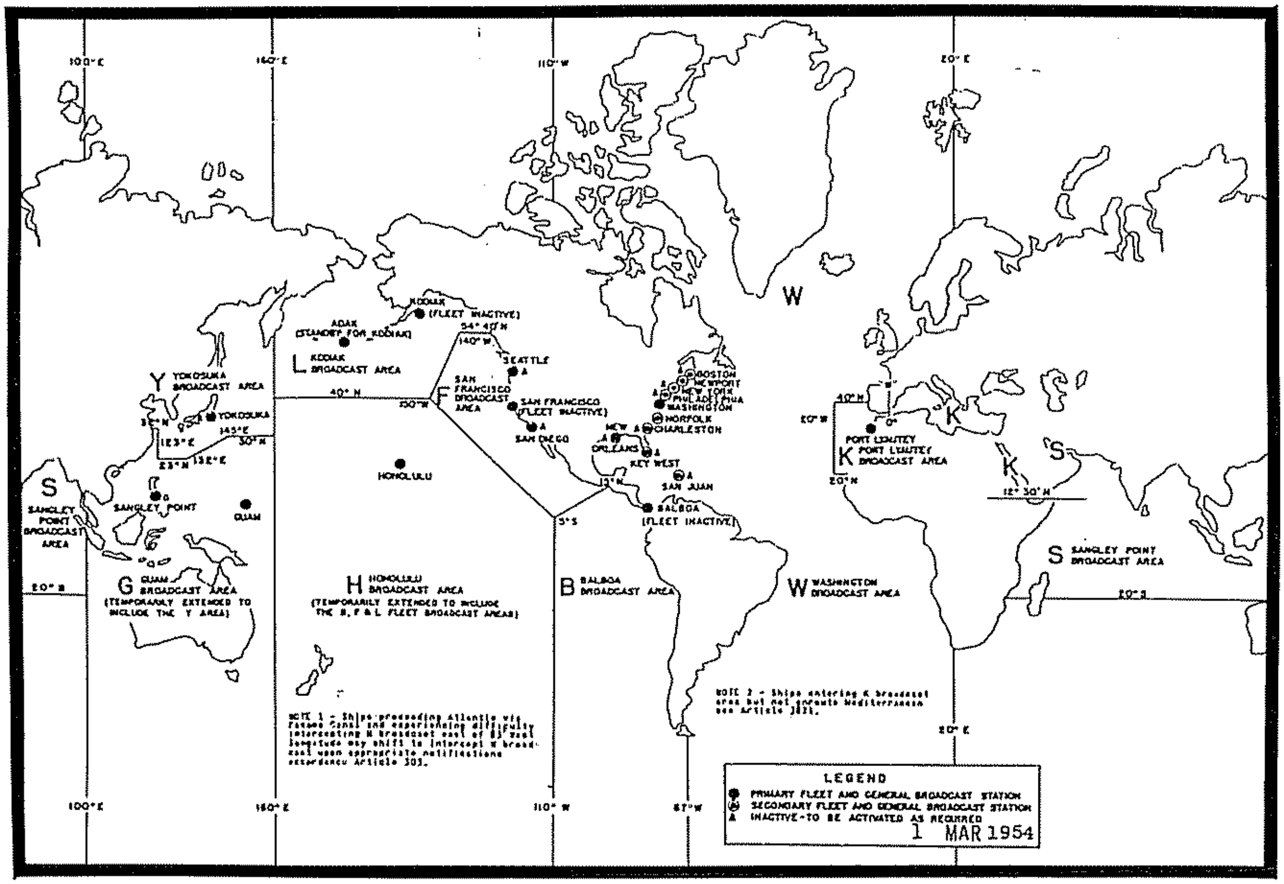


Figure 2. Map of primary and secondary fleet and general broadcast stations comprising the Naval Communication System (United States Navy, Bureau of Naval Personnel, *Shore Based Communications*, 1954, p.6).

Figure 3. Aerial photograph of Naval Communication Station in Washington, DC, May 22, 1952 (Courtesy of the National Archives and Records Administration, Still Photo Branch).

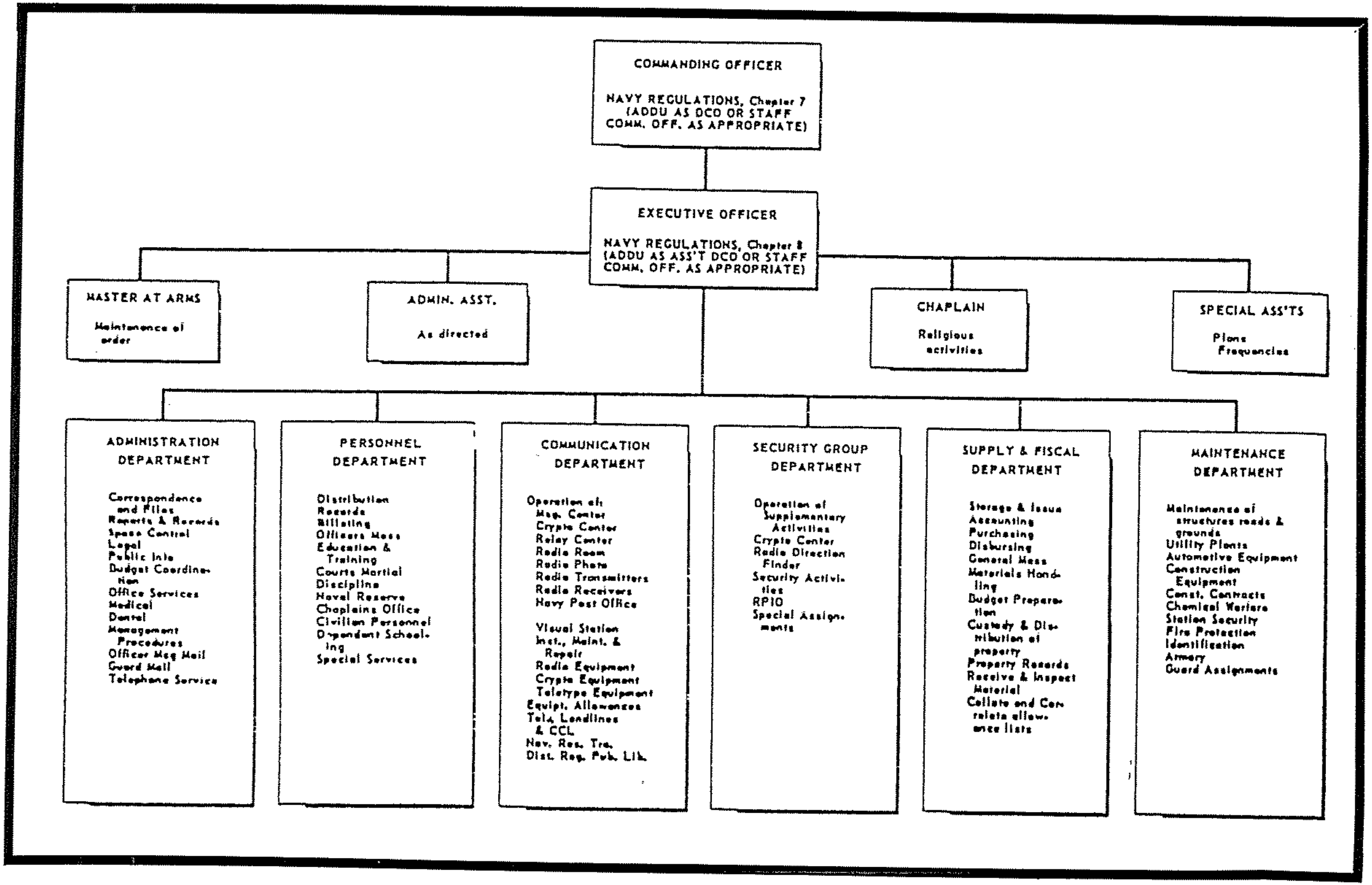


Figure 4. Functional organization of a Naval Communication Station (NAVCOMMSTA). The typical NAVCOMMSTA is organized into six departments, including administration, personnel, communications, supply and fiscal, security group, and maintenance (United States Navy, Bureau of Naval Personnel, *Shore Based Communications*, 1954, p.8).

Station Fifth Naval District Headquarters (Figure 5). In 1948, a new communication center (Building M-51) was constructed. The facility was redesignated U.S. Naval Communication Station Norfolk in 1950.[89] As part of Norfolk's expansion plans, a receiving station at Northwest, Virginia and a transmitting station at Driver, Virginia were established. The Northwest and Driver sites were chosen for their geographic isolation that was free from interference; critical factors in the overall performance of relaying radio signals. Construction at both sites was initiated during the early 1950s, and followed standard policies adopted by the Bureau of Yards and Docks.[90]

The Naval Radio Transmitter Facility (NRTF) Driver was opened officially in 1955. NRTF Driver was divided into two areas: the operations area containing the transmitter building and antenna field, and the support area containing administration, housing, and infrastructure. The transmitter building and its surrounding antenna field occupied the center of the installation. The transmitter building served as the main operations building and contained all the transmitter equipment. The transmitter building contained ten basic transmitter types that were capable of continuous wave (CW), voice, frequency shift, and facsimile transmission. The transmitters ranged in power from 500 to 50,000 watts. By 1958, NRTF Driver operated 46 transmitters.[91] The surrounding antenna field was located one-half mile from the installation boundaries, as required by standard Navy policy. The antenna field was equipped with four 300-foot towers, one 800-foot tower, and one 220-foot tower. The types of antennas initially constructed were able to transmit at all frequencies. These antenna systems connected the installation with Naval Radio Receiving Station, Northwest and the communications center located at Norfolk Naval Base.[92]

The Naval Radio Receiving Station Northwest was established in 1951 to provide radio receiving services for commands in the Norfolk naval complex. The radio receiving station had the capability of relaying messages from ships at sea and communication bases throughout the world. The communications facilities at Northwest, however, were not equipped to originate radio messages. Construction activities were initiated in December 1951 and largely were completed by March 1953 at a total cost of $4 million. The installation was commissioned in January 1954 and activated in May 1955. The installation was similar in layout to Driver. Operations and support areas were separated into two discrete entities. Operations facilities included a receiver building (Building 14), a 355-foot receiver tower (Building 18), and a one-mile circular antenna field. The antenna array, which surrounded the receiver building, contained 57 antennas that could be aimed in different directions to pick up radio signals from all parts of the world. The tower relayed the signals, on microwave lengths, to the Norfolk Naval Base. The circular antenna field has been demolished.[93]

In 1956, additional radio stations were constructed in the Antarctic at Little America, McMurdo Sound, and Marie Byrd Land. The Navy's first high-powered radio station, NAA Arlington, was disestablished during that same year. The station was reactivated two years later as a Naval Reserve Master Control Radio station for operational control and training.[94] In 1956, Congress appropriated funds to purchase a 2,850-acre peninsula in Cutler, Maine, for the establishment of a VLF station. The Naval Communications Unit Cutler represented an ideal site for locating the massive antenna system required for a VLF installation. Construction was initiated in January 1958 and the station was commissioned formally on June 23, 1961. The VLF transmitter installed at Cutler had a nominal power of two million watts. The communications system included two antenna arrays composed of thirteen, 800-foot to 900-foot towers and 75 miles of phosphorous bronze wire. A power plant also was constructed, and was capable of producing 14.5 million watts at peak output.[95] The Navy established other VLF sites at Summit, Panama Canal Zone; Lualualei, Hawaii; Haiku, Hawaii; and Northwest Cape, Australia.[96]

In 1959, automatic switching stations were installed at Cheltenham, Maryland; Norfolk, Virginia; and Stockton and San Diego, California. This resulted in the disestablishment of naval communication units (NAVCOMMUs) at Charleston, South Carolina, and New Orleans, Louisiana. The new automatic switching system provided connections between 85 stations with Trenton, New Jersey.[97]

Establishment of the Naval Security Group Activity (NSGA)

Several Naval Security Group Activity (NSGA) installations were established by the Navy to operate High Frequency Direction Finding (HF/DF) ground communications and surveillance systems. The primary mission of these facilities was to provide communications-related support including communications relay, communications security, and communications manpower to Navy and other Department of Defense elements. These facilities, which were established throughout the United States and overseas, were tasked with gathering information from enemy communications, radars, and missile tests.98

Domestic sites were established at Charleston, South Carolina; Key West, Florida; Homestead, Florida; Sugar Grove, West Virginia; and, Winter Harbor, Maine. The Naval Radio Station in Winter Harbor, Maine, received a Naval Security Group (NAVSECGRU) detachment unit in 1950. The following year, a circular antenna array was constructed to support this new activity. In 1958, the radio station was redesignated as NSGA Winter Harbor. By 1960, a "Wullenweber" Circularly Disposed Antenna Array (CDAA) and its associated operations building (Building 85) were constructed to replace the original circular array.

The Naval Radio Station (R) Northwest, which was established as part of the communication network for the Norfolk naval complex, revised its original mission with the commencement of Signals Security (SIGSEC) monitoring operations in April 1956. Northwest functioned as the Atlantic Operations Center and was responsible for coordinating and supervising all communications security (COMSEC) and selected electronics security (ELSEC) operations. Northwest became independent of the Norfolk Naval complex in 1975 when it was reassigned to the Commander of the Naval Security Group (NAVSECGRU) Command. NSGA Northwest was tasked with the mission of providing cryptologic and communications support to the Atlantic Fleet and elements of NATO operating throughout the Atlantic and Caribbean area NSGA Northwest assumed additional responsibilities as a result of its revised mission. The installation operated a HFDF Net Control center, a communications relay center, and the Atlantic Communications Security Operations Center (LANT COC). The HFDF Net Control facility provided locational and navigational services to the fleet. The installation also provided training support to Atlantic Fleet units and commands in security procedures, such as circuit monitoring and analysis.99

Overseas communications sites also were established, including Edzell, Scotland; Sabana Seca, Puerto Rico; Karamursel, Turkey; and Rota, Spain. The Edzell, Scotland, facility was acquired by the Navy in 1960; between 1951 and 1958 the site was operated as a U.S. Air Force radio facility. The main interception equipment at this facility included an AN/FLR-12 circular antenna system, which measured 1,640 feet in diameter and 66 feet high. Targets for the antenna system included Soviet naval activity in the North Sea, and troop and armor movements in Eastern Europe and the Soviet Union.100

In 1962, NSGA was established as a tenant organization at the Navy Radio Receiver Facility (RRF) in Sabana Seca, Puerto Rico, under the command of the U.S. Naval Communications Station Puerto Rico. Facilities for a Circularly Disposed Antenna Array (CDAA) were constructed to support this activity. In July 1971, responsibility was conveyed to the Naval Security Group (NAVSECGRU) Command and the installation was redesignated as the U.S. Naval Security Group Activity (NSGA) Sabana Seca.

The NAVSECGRU Command acquired another overseas site in Karamursel, Turkey in 1965. During the mid-1950s, the USAF operated a ground-based site at this location. Under the Navy's command, the facility contained a field of rhombic antennas and an AN/FLR-9 antenna system. Despite its remote location, the Karamursel site was a station of major importance during the 1960s. One target for these antenna systems included monitoring communications from Soviet air and naval activity in the Black Sea area. The Black Sea was the Soviet training ground where new equipment and operational doctrine were tested.

Figure 5. Building Z-86 was constructed in 1947 at Naval Base Norfolk to serve as the U.S. Navy Communication Station Fifth Naval District Headquarters.

Encrypted messages intercepted at the site were transmitted to NSA headquarters in Fort Meade, Maryland, for analysis. Karamursel also monitored various Soviet missile and space launches. Karamursel captured the conversation between Soviet Premier Aleksei Kosygin and Cosmonaut Vladimir M. Komarov during which Kosygin consoled the doomed Komarov, who had been informed that the braking parachutes of his space capsule were malfunctioning. By the early 1970s, the Karamursel facility's main function was to track Soviet naval traffic in the western Black Sea and the Dardanelles area. In 1975, Karamursel was closed by Turkey in response to an arms embargo imposed on Turkey.101

The Vietnam Era: 1961-1972

The antiquated condition of the State Department's communications network was made clear as a result of the Cuban missile crisis. While Russian ships armed with missiles headed toward Cuba, messages that should have passed between President Kennedy and Premier Krushchev in minutes took hours in transit. In some cases, Washington received word through Russian radio broadcasts hours before they were delivered to the White House. This situation revealed a number of problems with the existing communication network and led to sweeping changes in the structure of military intelligence. One major change was the creation of the National Communications System. The communications department within the State Department also was completely revamped.102

In 1961, Secretary of Defense Robert McNamara set up a new joint-service organization, the Defense Intelligence Agency (DIA), to consolidate intelligence activities of each military branch and to minimize a duplication of efforts. Prior to this, the military services were involved in coordinating and funding their own collection programs. These programs often overlapped in their collection efforts. Much of the military analysis undertaken by the DIA is a duplication of the CIA's efforts. As a result, there is much rivalry between the two organizations.103

The Vietnam War presented the United States with some of the most trying experiences in its history. Abroad, the United States committed its military forces to preserve democracy in South Vietnam. At home, the government faced a strong anti-war movement. American involvement in Vietnam began to grow in 1961 when the Viet Cong, an insurgent movement controlled by Communist North Vietnam, stepped up activities against the South Vietnamese government. By 1963, the United States had committed 23,000 Americans in South Vietnam. Once U.S. troops entered Vietnam, intelligence and security needs drastically increased.104

The Vietnam War was a "low-level conflict fought with the aid of high-level technology".105 This was especially true in the intelligence field, which utilized a whole array of sophisticated electronic, electro-optical, acoustic, and chemical techniques to detect enemy presence. Ground surveillance radars, which were first introduced in the late 1950s, were used to monitor the approach of enemy personnel.106

<u>Expansion of the U.S. Naval Communication Station (NAVCOMSTA), Roosevelt Roads, Puerto Rico</u>

The U.S. Naval Communication Station (NAVCOMSTA) at Roosevelt Roads, which was established as the primary Defense Communication Agency (DCA) in Puerto Rico, was expanded during this period with the construction of three communications stations at Isabela, Aguada, and Salinas. In 1962, a transmitter site was constructed at Fort Allen on Puerto Rico's south-central coast. Transmitters and receivers were installed at Isabela and Salinas the following year. The communications headquarters initially were located in San Juan, but were relocated to Fort Allen in 1970.107

The Naval Radio Receiver Facility, Salinas operated as a high-frequency (HF) receiver site from 1963 until 1976, at which time these operations were shifted to Sabana Seca. In

1965, the Navy acquired land from the U.S. Air Force to establish the Naval Radio Transmitter Facility (NRTF) Isabela. NRTF Isabela was established in northwestern Puerto Rico to operate as a HF transmitter site. In 1968, the Naval Low Frequency Transmitter Facility (NLFTF) Aguada was established along the northwest coast of Puerto Rico. Prior to the Navy's acquisition, the Aguada site was used by the U.S. Air Force as a low-frequency (LF) site. The Navy established the Aguada site to operate as a nuclear submarine broadcast site. The site supports a 250-kilowatt (kw) low frequency transmitter capable of radiating 100 kw at an operating frequency of 28.5 kilohertz (KHz).108 Similar LF sites established in the U.S. included Cutler, Maine; Jim Creek, Washington; and Annapolis, Maryland (closed). Overseas sites were constructed at Lulu Lake; Australia; and Japan (closed).109

Role of Early Satellite Communications

The move of reconnaissance activities into space in the 1960s represented one of the most important developments in U.S. intelligence. Satellites became instrumental in performing a variety of intelligence missions, including imagery collection, SIGINT collection, communications, and early warning. Unlike ground communication networks, satellites were capable of amplifying several signals simultaneously using a single repeater.110

The intelligence community began to consider proposals for reconnaissance satellites almost ten years before the launch of the Soviet Union's Sputnik I. The U.S. launched its first telecommunications satellite, SCORE (Signal Communication by Orbiting Relay Equipment), on 18 December 1958, one year after the Soviet Union launched its first Sputnik satellite. SCORE was fitted with a time-delayed relay system that recorded and later transmitted stored messages by remote control. SCORE transmitted the first voice communication from space when it beamed President Eisenhower's pre-recorded Christmas message.111

The U.S. initiated the Discoverer program in 1959, which represented the first series of U.S. photo-reconnaissance satellites. Discoverer's objective was to place a series of satellites in orbit 567 miles over the Soviet Union and return whatever information they collected to earth in special capsules. The project performed poorly, with only 26 of the 38 satellites reaching their designated target. Capsules were ejected on only 23 and only twelve were recovered successfully. The Discoverer program was discontinued by 1962. The program, however, was not a complete loss. One of the first recovered capsules yielded valuable information about the Soviet Union's nuclear program by providing approximately 6,200 photographic images depicting an 115 square mile area in great detail.112

Prior to 1960, each of the three military departments operated separate, long-haul communications systems that linked various activities around the world. The Defense Communications Agency (DCA) was established in 1960 to oversee the satellite communications field. DCA was responsible for managing all of the long-haul, point-to-point circuitry for the worldwide military command and control systems. Initially, DCA utilized a medium-altitude random orbiting satellite system complemented by a family of air transportable ground stations.113 During the 1960s, most overseas communications were channelled across the Atlantic via one of two Intelsat satellites in permanent, geosynchronous high orbit. Each of the two satellites were capable of accommodating up to 4,000 telephone circuits. Ground bases to support the satellite traffic were established at Andover, Maine; Etam, West Virginia; Madley, Herefordshire; and, Goonhilly, Cornwall. By the end of 1967, NSA had constructed, under secret cover, two identical receiving stations at Winter Harbor, Maine and Sugar Grove, West Virginia. Two similar bases were established in Yorkshire and Morwenstow in England. NSA also established a secret annex at the U.S. Naval Communication Station at Asmera in Eritrea. Two signals centers also were established at Port Lyautey in Morocco and in Greece.114

Throughout the 1960s, the Satellite Communications Program was expanded through collaborative efforts between private industry and the military. Early programs included the development of synchronous altitude orbital techniques; experimentation into commercial relay capabilities by the American Telephone & Telegraph (AT&T) Corporation; and experimentation into low altitude active satellite repeaters by NASA for military applications.115

On July 20, 1962, the first television picture was retransmitted by Telstar between Andover, Maine, and the French station at Pleumeur-Bodou. Soon thereafter, the Soviet Union succeeded in establishing the first interspace link between two manned satellites. In 1965, the "Early Bird" (Intelsat I) became the first of a series of world coverage television satellites, which linked 101 countries and claimed a monopoly over intercontinental satellite communications 116

One of the first satellite programs to succeed the Discoverer program was the "Big Bird" platform developed by Lockheed and launched in June 1971. The system was designed to relay SIGINT material to ground stations connected to the skynet system; the Navy facility at Pine Gap near Alice Springs, Australia was one of the ground facilities. Big Bird contained a giant camera built by the Perkin-Elmer Corporation that had a lens capable of an eight-inch resolution from a height of 110 miles. The first Big Bird satellite, however, had a short lifespan and burned upon reentering the earth's atmosphere. Additional Big Bird platforms have been launched since 1971. Information collected during these subsequent launches was transmitted to five stations around the world, including Guam, the Seychelles, Oahu, Ascension, and New Boston. Guidance signals were transmitted from control stations at Kodiak Island, Alaska and Vandenburg Air Force Base, California.117

In 1971, the Navy's Fleet Satellite Communications System (FLTSATCOM) was approved. The system was designed to provide multi-channel UHF broadcast service to all Navy ships, as well as providing command and control links among shore stations, fleet ballistic missile submarines, aircraft carriers, and other ships and submarines. The original plans included four satellites in geostationary orbit to provide global coverage. These satellites, which were launched in 1978, were positioned over the Pacific, Atlantic, and Indian Oceans. The Navy's FLTSATCOM system is supported by satellite communications (SATCOM) earth stations.118

The Navy's Satellite Communication Research Facilities

During the early 1950s, NRL was involved in conducting experiments to study the characteristics of moon-reflected radio energy. In 1951, the laboratory constructed the world's largest parabolic antenna at Stump Neck, Maryland. By July 1954, NRL was able to transmit human voices through outer space to the moon and back using this large antenna. In November 1955, NRL was successful at transcontinental satellite communication from Washington, DC, to San Diego, California. In 1956, NRL constructed an "S-band facility" that had a 60-foot steerable parabolic antenna on its rooftop. Many of its original satellite experiments were carried out from this facility.

Based on NRL's successful research, the Navy operated its first worldwide satellite communications system between 1964 and 1969. The system included six ship and four shore installations with satellite communication terminals at Cheltenham, Maryland; Wahiawa, Hawaii; Okinawa; and Oakhanger, England. Each station employed eighty-four foot diameter, steerable parabolic antennas.119

In 1961, NRL's Low Frequency Trans-Ionospheric (LOFTI) satellite was launched to aid in the study of VLF radio signals. Although burned in the atmosphere after six weeks, the satellite collected important data about passing LF waves through the ionosphere. During that same year, NRL established the Sugar Grove Satellite Communication Research Facility in Sugar Grove, West Virginia. Sugar Grove was selected due to its sky coverage, low radio noise level, and meteorological and geophysical characteristics. A 60-foot parabolic reflector was installed at this site during the mid-1960s to support NRL's space research projects. The dish was automatically steered using digital computer technology and was capable of achieving frequencies up to 4000 MHz.120 The parabolic reflector was attached to huge turntable tracks which rotated the dish upwards "not only to pick up strange sounds from outer space, but also echoes and signals from missiles and satellites". 121 The NRL subsequently designed and installed a 150-foot parabolic antenna at its Sugar Grove site. 122

NRL established a new research facility, the Waldorf Satellite Communication Research Facility, at Waldorf, Maryland, in 1967. The NRL facility, a former Nike missile site, had capabilities superior to any of its type and was effective at frequencies as high as 20,000 MHz. The site consists of a 60-foot parabolic antenna supported by buildings to house a 25-kw transmitter, antenna control, computer control, data processing, receiving and modem equipment, and laboratory space. 123

NSA also relied on satellite communication to carry out their surveillance mission. NSA utilized a subseries of the SAMOS (Satellite and Missile Observation System) satellites that were used to photograph and televise pictures of missile bases, encampments, and other areas of interest. A series of "ferret" satellites also were used by NSA as part of their electronic intelligence efforts. Ferret satellites monitor radio and radar signals from geosynchronous orbits in space, and are capable of capturing radio traffic of foreign military units, radar and telemetry data from missile tests, and private communications of foreign leaders. 124

Post-Vietnam Era: 1973-1989

Advancements in Satellite Communications

During the 1970s and 1980s, technology advanced through such developments as low earth orbit satellites, which were capable of obtaining highly detailed images and quickly relaying them to earth. Some systems operated from high orbits to monitor Soviet naval activities. Others operated in geosynchronous orbit from 22,300 miles above the earth's surface, and represented a major advancement in signals intelligence capabilities. 125

The proliferation of space reconnaissance systems provided the still-secret National Reconnaissance Office (NRO) with a yearly budget of several billion dollars, and placed NRO at the center of the intelligence process. During the early 1970s, work was initiated on a new satellite, Rhyolite. The satellite was capable of intercepting signals across the VHF, UHF, and microwave frequency bands and simultaneously transmitting 11,000 two-way telephone conversations. These features proved invaluable for intercepting and analyzing data from Soviet missiles in flight. 126 The Rhyolite satellite consisted of "a huge radio 'ear' turned to earth, banks of solar cells to provide power, and a transmitter to send signals back to the ground."127

The first Rhyolite satellite appears to have been launched in June 1970. Four additional satellites were launched in March 1973, May 1977, December 1977, and April 1978. All of the satellites were launched from Cape Canaveral using a General Dynamic/Lockheed Atlas-Agena booster. Two of the satellites apparently were stationed near the Horn of Africa to receive telemetry signals transmitted from intercontinental ballistic missiles (ICBMs) launched from Tyuratam. The other two satellites were stationed over Borneo to monitor Soviet solid-propellant missiles launched from the space-launch facility at Plesetsk. Together, these satellites provided coverage of almost all of the Soviet Union, Africa, Europe, Asia, and the Middle East. In 1975, the Rhyolite program suffered a serious setback when technical data on the satellite was sold to the KGB. 128

Rhyolite satellites were controlled from the Pine Gap facility in Australia, which served as the Joint Defense Space Research Facility and was code-named MERINO. The facility contained seven large radomes, a huge computer room, and miscellaneous support buildings. The radomes were described as "golf balls with one end sliced off and then mounted on a pedestal, are made of Perspex and mounted on a concrete structure."129 The radomes protected the delicate antenna equipment from the elements, as well as from unfriendly observation. The first two radomes were installed in 1968 and represented the largest at the Pine Gap facility, measuring between 70 and 100 feet in diameter. A high-frequency antenna was installed at the northern edge of the complex and provided a direct communications link with Clark AFB.130

The mid to late 1970s saw the further deployment of space-based signals intelligence satellites. On 10 March 1975, the first satellite belonging to a class of elliptically orbiting satellites, code-named JUMPSEAT, was launched from Vandenburg AFB. In 1975, another SIGINT satellite was launched into geosynchronous orbit from Cape Canaveral.131

In April 1976, the U.S. Navy acquired its first operational ocean surveillance satellite system. The space and ground elements of the system were designated CLASSIC WIZARD, and the satellite portion was named WHITE CLOUD. Satellite communications technology soon supplanted HF radio technology, making much of the Navy's communications systems obsolete.132

Role of Military Communications and Surveillance Activities

By the 1970s, a whole series of signals intelligence, ocean surveillance, and nuclear detection stations had emerged. These sites were operated by the different military services, including the Air Force Electronic Security Command and the Naval Security Group Activity (NSGA) Command. Sites were situated at Adak, Attu, Burnt Mountain AFS, Elmendorf, and Eielson. In most cases, these sites operated a variety of antennas for HF/DF operations, signals interception, or seismic monitoring equipment.133

The 1970s marked the beginning of the modern era of radio communication with the "transistorization" of equipment, which resulted in improved performances, increased reliability, and lower prices. Digital wide band radio links were introduced in 1975, paving the way for greater advancements in communication technology. By this date, the military intelligence community had come to rely on sophisticated technical systems for collecting and processing data. By the mid-1970s, programs for SIGINT collection and processing, cryptography, satellite reconnaissance, and other complex, expensive technical activities accounted for the bulk of the intelligence budget.134

Following the Vietnam War, the CIA and the intelligence community underwent a series of budget cuts. By 1976, U.S intelligence analysis had lost much of its stature. The first years of the Reagan Administration were marked by the resurgence of the intelligence community. By 1985, the defense build-up started in the late 1970s had begun to decline. Intelligence spending, as a result, experienced a decline.135

Conclusion

During the nearly 50 years of the Cold War, the United States Navy's communication program played an important role in military operations and American security. The Navy's communication program took shape at the beginning of the twentieth century with the introduction of radio as a viable means of communications. As the twentieth century progressed and radio technology matured, the Navy upgraded its systems to keep pace with the latest technological developments. By World War I, the Navy had established a small chain of high-powered communications stations. The World War II period was characterized by great strides in the development of electronics applications. During this period, communications frequencies moved into the microwave range. Improvements in vacuum tube technology also were made. Most importantly, R&D efforts during the war resulted in significant breakthroughs in radar technology.

With the onset of the Cold War, communications evolved into a large and important operation within the Navy. During this period, the Navy's communication program expanded into a sophisticated network of communications and surveillance facilities. Radar technology, which made its debut during World War II, has advanced significantly as a result of the introduction of solid state digital technology in recent years.

Throughout the early- to mid-twentieth century, the Navy relied on the high frequency (HF) spectrum as the primary mode of military communications. The 1970s marked a major turning point in communication technology with the move of reconnaissance activities into space using satellites. As a result, the Navy's HF systems are being replaced slowly by a new generation of communications facilities, known as satellite communications (SATCOM) earth terminals. By the close of this decade, a sophisticated network of signals intelligence, ocean surveillance, and nuclear detection stations had emerged. Although the Cold War has ended, the Navy's communications program continues to play a crucial role in protecting American interests.

CHAPTER IV

PROPERTY TYPES ASSOCIATED WITH THE NAVY'S SHORE-BASED COMMUNICATION PROGRAM

Introduction

The Navy Cold War Communication Context was designed to support the identification and evaluation of buildings, structures, sites, and districts associated with the Navy's shore-based communications program. Table 1 illustrates the range of built resources associated with the Navy's Cold War communication program. This chapter provides an overview of specific property types constructed to support the Navy's Cold War communications program illustrated by representative examples. It is anticipated that the categorization of resources by property types will assist cultural resource managers in assessing the comparative importance of Cold War real property.

For the purposes of analysis, property types were divided into two general categories: (1) shore-based communications facilities and (2) shore-based communication and surveillance systems. These general categories were further analyzed to identify the major property types within each category. For example, shore-based communications facilities were divided into four sub-categories: (1) transmitter stations; (2) receiver stations; (3) communication centers; and (4) direction finder (D/F) stations. Shore-based communication systems were divided into the following sub-categories: (1) search radars; (2) direction finders (D/F); (3) tropospheric scatter systems; (4) extremely low frequency (ELF)/very low frequency (VLF)/low frequency (LF) systems; (5) high frequency (HF) systems; (6) very high frequency (VHF) systems/ultrahigh frequency (UHF) systems; and (7) satellite systems. Medium frequency (MF) systems were not discussed since this frequency band was used primarily for commercial purposes and, therefore, did not have a military application.

Property types were developed through a combination of archival research and architectural field investigations. Archival research was undertaken to anticipate the range of property types associated with the Navy's Cold War communications program; field investigations then were conducted to verify and to refine the property types. Construction drawings at each installation were examined to provide graphic data for type identification and analysis. Navy installations visited as part of the field investigations included: Naval Security Group Activity (NSGA) Northwest; NSGA Sabana Seca; NSGA Winter Harbor; Naval Radio Transmitter Facility (NRTF) Annapolis; NAVCOMTELSTA Isabela, Aguada, and Salinas; and, Naval Air Station (NAS) Keflavik. Appendix A should be referenced to obtain additional information on individual Navy installations associated with the Navy's Cold War communications program.

TABLE 1. PROPERTY CATEGORIES ASSOCIATED WITH THE NAVY'S COLD WAR COMMUNICATION PROGRAM

CATEGORIES OF COLD WAR PROPERTIES	ASSOCIATED PROPERTY TYPES	SELECTED EXAMPLES
Buildings	Operations Buildings	Operations Building (Building 60), NRTF Annapolis, Maryland Operations Building (Building 41), Naval Radio Station (R) Northwest, Virginia Operations Building (Building 3001), NRTF Isabela, Puerto Rico
	Transmitter Buildings	Transmitter Building (Building 5), NRTF Annapolis, Maryland HF Transmitter Building (Building 505), Mare Island, California Transmitter Building, Jim Creek, Washington
	Receiver Buildings	Receiver Building (Building 14), Naval Radio Station (R) Northwest, Virginia
	Terminal Equipment (TE) Buildings	Terminal Building, Naval Station Adak, Alaska NATO Satellite Communications (SATCOMM) Ground Terminal Building (Building 257), NSGA Northwest, Virginia
	Communication Centers	Communication center (Building 839), NAS Keflavik, Iceland
	Helix Houses	Helix House (Building 5A), NRTF Annapolis, Maryland Helix House (Building 2902), NLFTF Aguada, Puerto Rico
	Antenna Maintenance Shops	CDAA Complex, NSGA Northwest, Virginia CDAA Complex, NSGA Winter Harbor, Maine
	Support Buildings	Storage Building (Building 15), Naval Radio Station (R) Northwest, Virginia Power House (Building 3002), NRTF Isabela, Puerto Rico
Structures	Antenna Systems	LF "Marconi Triatic" antenna, NRTF Annapolis, Maryland Microwave Tower, Naval Radio Station (R) Northwest, Virginia "Wullenweber" Circularly Disposed Antenna Array (CDAA) system, NSGA Sabana Seca, Puerto Rico Conical Monopole HF antenna, Naval Radio Station (R) Northwest, Virginia Relocatable-Over-the-Horizon (ROTHR) antenna, NSGA Northwest, Virginia Inverted Cone Antenna, NSGA Northwest, Virginia
Objects	N/A	
Sites	Communications Sites	Dye-5 Site (Tropospheric Scatter System), NAS Keflavik. Iceland Remote Radar Sites (H-1, H-2, H-3, H-4), NAS Keflavik, Iceland
Districts	Operations Area	Naval Low Frequency Transmitter Facility (NLFTF), Aguada, Puerto Rico

SHORE-BASED COMMUNICATIONS FACILITIES

Classification of Shore Communication Facilities

The Navy's shore communication facilities are classified according to their intended use and can be divided into four major categories:

- Receiver stations
- Transmitter stations
- Communication centers
- Direction finder (D/F) stations

The following section presents an overview of the above-mentioned categories, and includes a discussion of the function and evolution of each category and the major property types (i.e., operations buildings, antenna array, and support buildings) associated with each facility. A discussion of general design characteristics and technological developments are provided for each property type.

Transmitters versus Receivers

Transmitters and receivers are designed to perform two basic functions. The transmitter is designed to generate a radio frequency signal of sufficient power at the desired frequency. It also has the ability of varying, or modulating, the basic frequency so that it can carry an intelligible signal. The receiver is designed to select the desired frequency to receive signals and reject all unwanted frequencies. Receivers also must be able to amplify weak incoming signals. Transmitters may consist of simple, low power systems capable of sending voice messages a short distance or more sophisticated, higher power systems that are capable of transmitting many channels of data (i.e., voice, teletypewriter, television) simultaneously over long distances.136

RECEIVER STATIONS

Introduction

Naval receiver stations perform radio receiving functions at a geographically distant location from the communication center of a naval communication station. A type designating letter (R) is added to the installation name to indicate its function.137

Evolution of Receiver Stations

The radio was adapted by the Navy in 1901 and the naval communication program began to take shape. Over the next fifty years, communications evolved into a large, complex, and important operation within the Navy. As the Navy expanded its communications efforts during the early-1950s, greater attention was paid to the design of new communications facilities.

In 1953, the Bureau of Yards and Docks established general design criteria for the siting, design, and construction of receiver facilities. Naval Radio Station (R) Northwest, Virginia, is a typical example of a Navy receiving station from this period. Established in 1953, Northwest's mission was to receive messages from ships at sea and communication bases throughout the world. The overall layout of the radio receiver station was divided into two distinct areas, including an operations area and support area. The support area consisted of administration offices, barracks, housing, and infrastructure facilities. The operations area contained a receiver building (Building 14), a receiver tower (Building 18), and a circular antenna field. The antenna field, which contained 57 omni-directional antennas, surrounded the receiver building.

The overall layout and types of built resources constructed to support a receiver station remained fairly constant over the following decades. Changes, instead, were made to the building's interior and its associated antenna systems in response to new technological developments and functional requirements.

Associated Property Types

Built resources associated with the operations area of a receiver station include receiver buildings, antenna array, and support buildings. The following discussion briefly describes these built resources, which are highlighted by representative examples.

<u>Antenna Array</u>

Naval radio communication facilities use various types of antenna for transmitting and receiving radio signals. During the 1950s, the typical antenna systems found at radio receiver stations included: antenna system supported between self-supporting or guyed towers; rhombic; wide-band doublets; tilted folded doublet; vee; vertical low frequency (LF); vertical doublet; vertical phased doublet; horizontal parasitic doublet; horizontal three-wire doublet; and, various UHF and VHF antennas (Figures 6 and 7).138

Antenna systems at the Navy's receiver stations were supplanted by newer, state-of-the-art systems as a result of technological developments and the expanding radio frequency spectrum. The section on Shore-Based Communication Systems provides a more-detailed discussion of the evolution and types of Navy communications systems.

Receiver Buildings

Receiver buildings represent an important property type associated with the Navy's Cold War communication program. These specialized facilities are the "heart" of a receiver station and contain the control equipment to operate the antenna array, power source, administrative space, and operations center for the associated antenna array. Due to its specialized function, the building was situated in an area that was isolated from other sections of the station. In most cases, the receiver building was situated near the center of the antenna field to reduce the length of the transmission lines.[139]

Receiver buildings are simple, utilitarian structures characterized by their minimal ornamentation and lack of window openings. Design guidelines prepared by the Bureau of Yards and Docks in 1953 outlined the general criteria for receiver buildings:

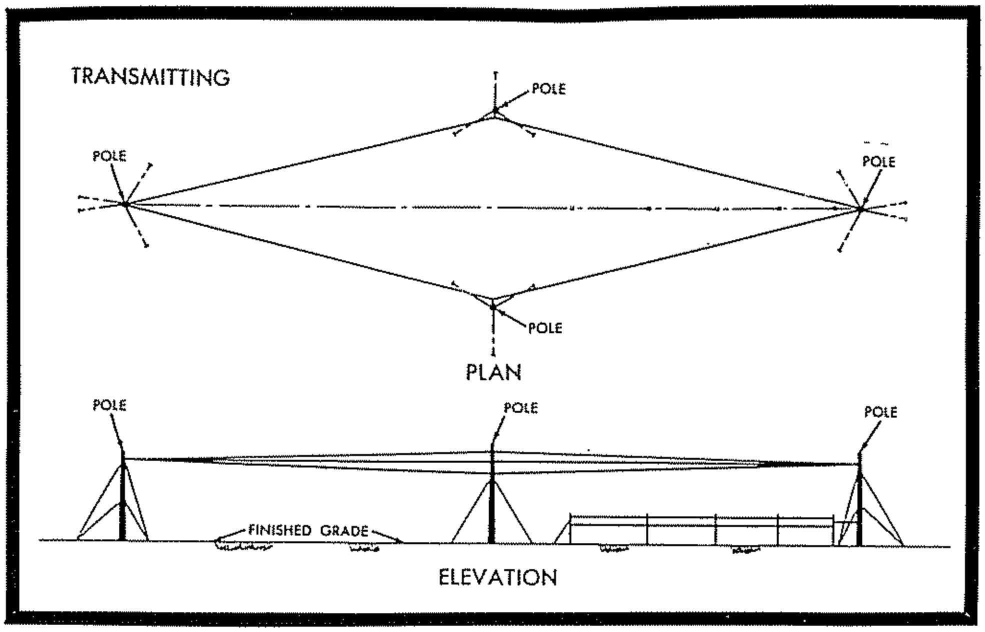
> Permanent receiver buildings should be of masonry or reinforced concrete construction, generally rectangular in shape...Interior partitions should be of metal or wooden studs and plaster or dry wall construction to allow rearrangement of operating space. Exterior walls (except doors, openings for ventilation and air conditioning, and cable entrances) are unpierced by windows. Such construction provides proper security without special shatterproof or bombproof design.[140]

The Bureau of Yards and Docks publication specified reinforced concrete or structural steel framing with cellular steel flooring for both the first and second floors. Certain interior rooms, such as teletype rooms and electronic repair shop, had to be "double shielded", requiring two layers of 16-mesh copper screening on floors, walls, and ceilings.[141]

The receiver building (Building 14) at the Naval Radio Station (R) Northwest provides an example of a typical 1950s receiver building. Building 14 was constructed in 1953 and operated in tandem with a receiver tower (Building 18) and a circular antenna field. Building 14 was designed as a two-story, reinforced concrete structure terminating in a flat concrete slab roof. A two-story tower occupied the northwest corner of the building. No window openings punctuated the building's exterior. A set of double metal doors on the west elevation provided access to the building. The first floor of Building 14 contained a receiver room, mechanical room, equipment area, and cable vault room (Figure 8). Three operations areas, an office, shop, secure area, and storage room were located on the second floor. The interior of Building 14 has been converted for use as offices, classrooms, and training facilities.

Support Buildings

Buildings constructed to support the operations area of a radio receiver facility typically include storage and maintenance buildings, and infrastructure facilities. The original layout of the operations area at the Naval Radio Station (R) Northwest comprised a storage building (Building 15) and a cable vault communications building (Building 17). Both buildings were situated north of the radio receiver building and were characterized by their reinforced concrete construction and utilitarian design.



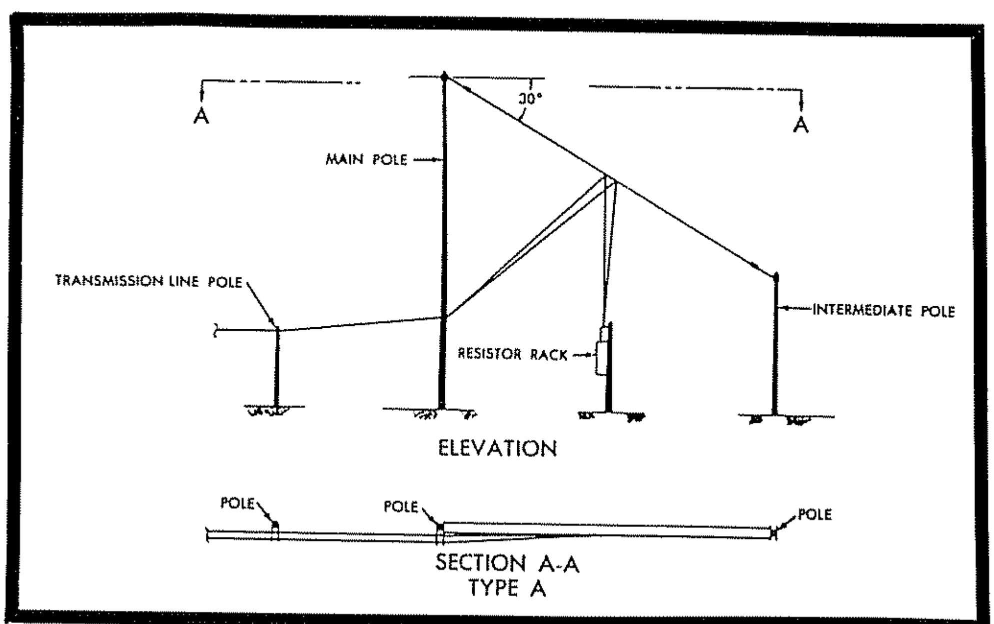
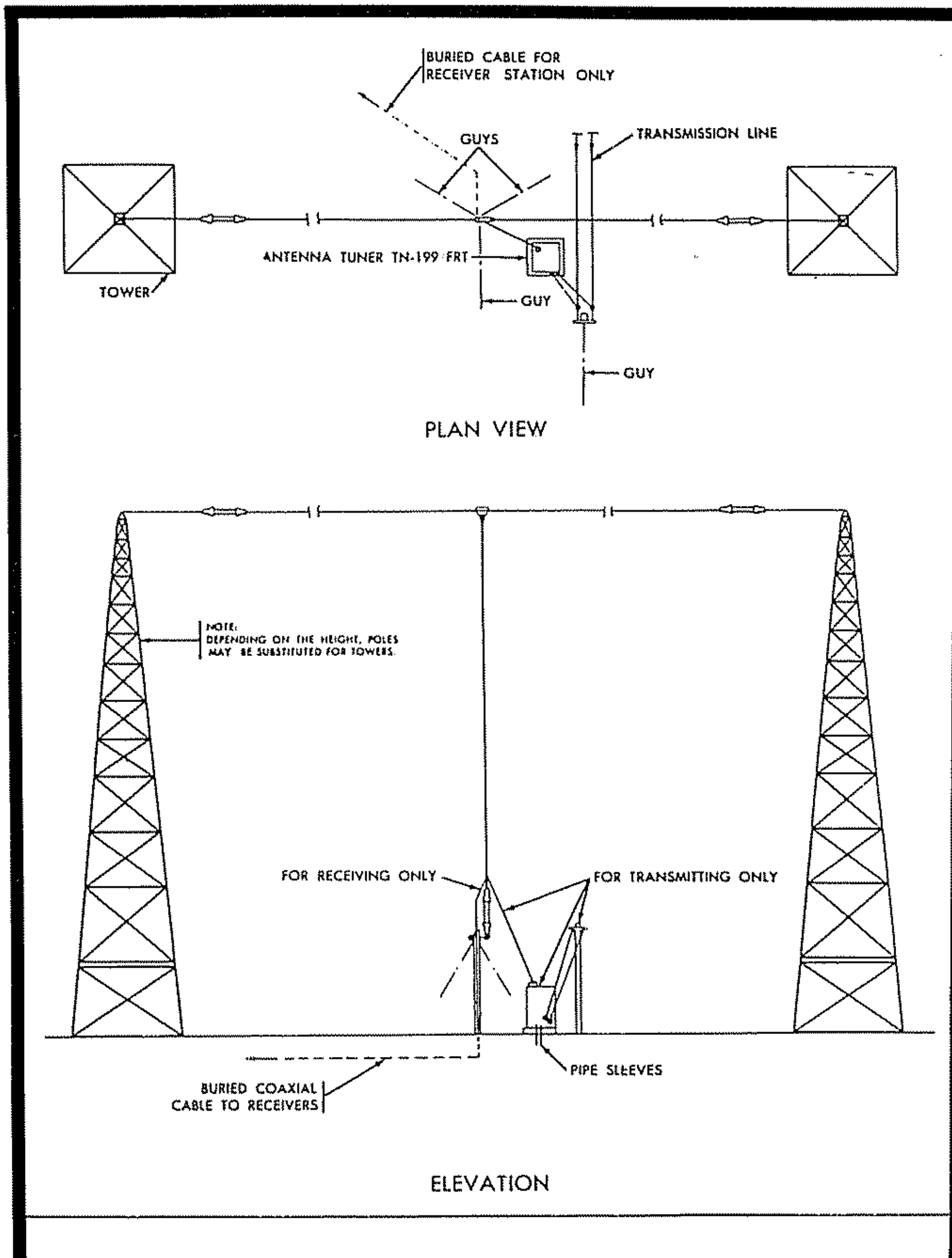


Figure 6. Above: Diagram of rhombic transmitting antenna. Below: Diagram of wide-band doublet transmitting antenna (United States Navy, Bureau of Yards and Docks, *Radio Communications Facilities, Shore Based*, 37 and 39).



Vertical Low Frequency—Transmitting and Receiving

Figure 7. Diagram of vertical low frequency (LF) transmitting and receiving antenna (United States Navy, Bureau of Yards and Docks, *Radio Communications Facilities, Shore Based*, 41).

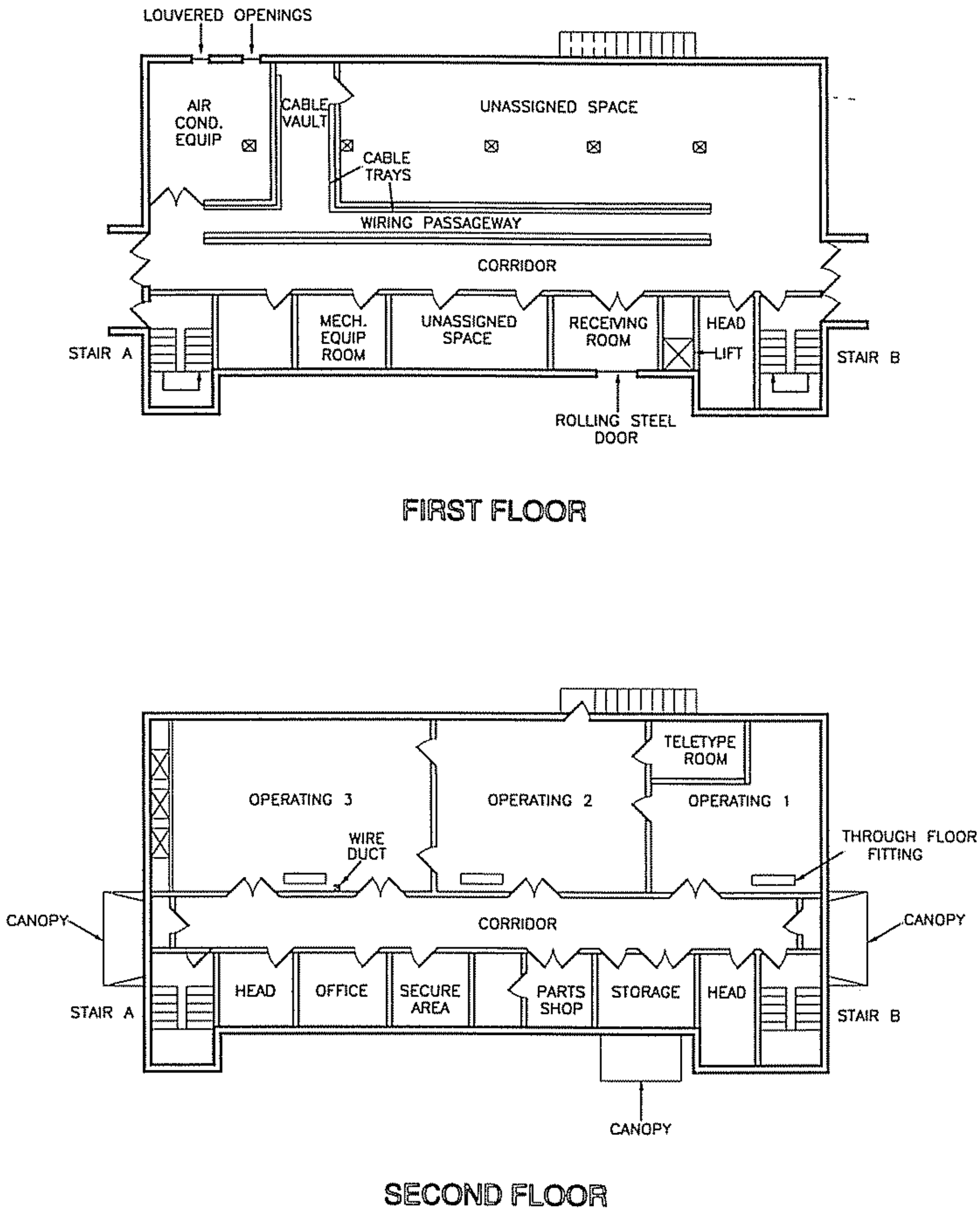


Figure 8. Above and below: First and second floor plans of radio receiver building (Building 14) at the Naval Radio Station (R) Northwest, Virginia.

TRANSMITTER STATIONS

Introduction

The primary purpose of a naval transmitter station is to perform radio transmitting functions from a location that is geographically distant from the communication center of a naval communication station. A type designating letter (T) is added to the installation name to indicate its function.142

Evolution of Transmitter Stations

The naval communications program began to take shape during the early 1900s when radio was first introduced as a viable means of communications for the Navy. Over the next fifty years, communications evolved into a large and important operation within the Navy. The Navy made great strides to expand its communications program during the early 1950s. During this period, greater attention was paid to the design and layout of new communications facilities. The Bureau of Yards and Docks, for example, developed general design criteria for the siting, design, and construction of transmitter facilities. Although the overall layout of transmitter stations remained fairly constant over the following decades, significant advances were made to the building's interior and associated antenna systems, which evolved in response to new technological developments and functional requirements.

The two transmitter facilities that comprise the U.S. Naval Communication Station (NAVCOMSTA), Roosevelt Roads, provide representative examples of circa 1960s transmitter sites. The Naval Radio Transmitter Facility (NRTF) Isabela, Puerto Rico, was established in 1965 to operate as a HF transmitter site. The administration and operations area contains seven buildings surrounded by an antenna field. The Naval Low Frequency Transmitter Facility (NLFTF) Aguada was established in 1968 along the northwest coast of Puerto Rico to operate as a LF nuclear submarine broadcast site. The Aguada facility is a small, self-contained site that consists of a 1,200-foot transmitting tower supported by an operations building, emergency power plant building, and a helix house.143

Associated Property Types

Built resources associated with the operations area at Naval transmitting stations include transmitter buildings, antenna array, and support buildings. The following discussion provides an overview of the major built resources and is highlighted by representative examples.

Antenna Array

Naval radio communication facilities use various types of antenna for transmitting and receiving radio signals. Antenna systems vary with the amount and type of land available, desired signal coverage, and bandwidth requirements. Typical antenna systems found at radio communications facilities during the 1950s included: top-hat (flat-top); vertical radiator; rhombic; wide-band doublets; tilted folded doublet; vee; vertical doublet; vertical phased doublet; horizontal parasitic doublet; horizontal two-wire and three-wire doublet; three wire beverage; and, various UHF and VHF antennas. A typical top-hat antenna consists of two or more lengths of wire running parallel to each other and supported by a vertical tower at each end.144

Antenna systems at the Navy's transmitter stations were supplanted by newer, state-of-the-art systems as technological developments were introduced and the radio frequency spectrum expanded. The following section on Shore-Based Communication Systems provides a more-detailed discussion of the evolution of the Navy's communications equipment.

Transmitter Buildings

Transmitter buildings represent the most important property type constructed to support the Navy's transmitter stations. These specialized facilities contain the electronic equipment, power source, administrative space, and operations center for the associated antenna array. Typically, the transmitter building was situated near the center of the antenna field to reduce the length of the transmission lines.145

Transmitter buildings are simple, utilitarian structures characterized by their minimal ornamentation. The transmitter building (Building 5) at NRTF Annapolis is an early example of an operations facility specifically built to support the Navy's communications program. Building 5 was constructed in 1918 to serve as the main control facility for the original Poulson arc transmitter (Figure 9). The building was designed to incorporate a helix house, which housed the tuning equipment, adjacent to the operations wing. The one-story brick transmitter building was characterized by its Classical Revival design. The original design was dominated by eight bays of arched openings across the primary and rear elevations; these openings subsequently have been infilled with brick. The interior of Building 5 housed the control console for the transmitter. Much of the original equipment has been replaced to keep pace with the latest technology.

Operations buildings underwent minimal change in terms of its architectural design throughout the World War II period. A later operations building (Building 60) at NRTF Annapolis illustrates this point (Figure 10). Building 60, which was built in 1941 to house the power source for the low frequency (LF) "Marconi Triatic" antenna, was designed as a two-story brick structure terminating in a flat parapet roof. The plan of the building consisted of a central double-loaded corridor with three wings extending from each side.

Transmitter buildings from the early 1950s continued to be characterized by their utilitarian appearance and minimal ornamentation (Figure 11). The Bureau of Yards and Docks outlined the design requirements of a typical 1950s transmitter building as follows:

> Transmitter buildings are designed for blast-resistant construction and are therefore windowless. All steel reinforcing material must be completely bonded together and grounded to prevent excessive heating and losses in the presence of high intensity radio-frequency (RF) fields.146

The transmitter building consisted of two main elements, the transmitter room and the head house. The transmitter room was designed with an overall width of 50 feet to accommodate four rows of transmitters. The head house was centrally located on one of the long sides of the transmitter room. The interior typically contained shop and storage spaces, the communications control link (CCL) and switch gear, bunk and toilet facilities, office space, mess, and the principal access to the transmitter room.147

Many transmitter buildings constructed during the 1950s employed reinforced concrete, as opposed to the earlier examples of brick masonry construction. The transmitter building constructed at Jim Creek, Washington, one of the Navy's most powerful VLF transmitter facilities, was constructed of reinforced concrete with copper sheathing installed along both the walls and roof of the structure (Figure 12). Huge coils exit the building and connect to the immense antenna array.

The operations building (Building D-10) at NRTF Driver represents another typical transmitter building from this period. Building D-10 was completed in 1953 and was situated prominently at the center of the station's antenna array (Figures 13 and 14). The structure was constructed as a massive, reinforced-concrete building that adopts a cross-shaped footprint and

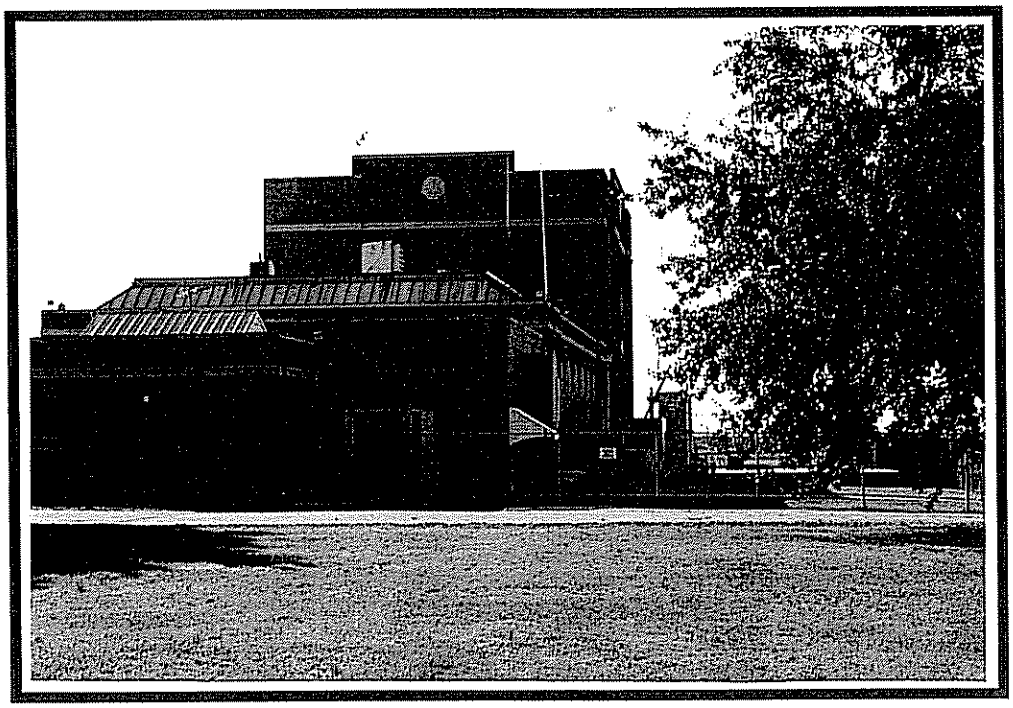
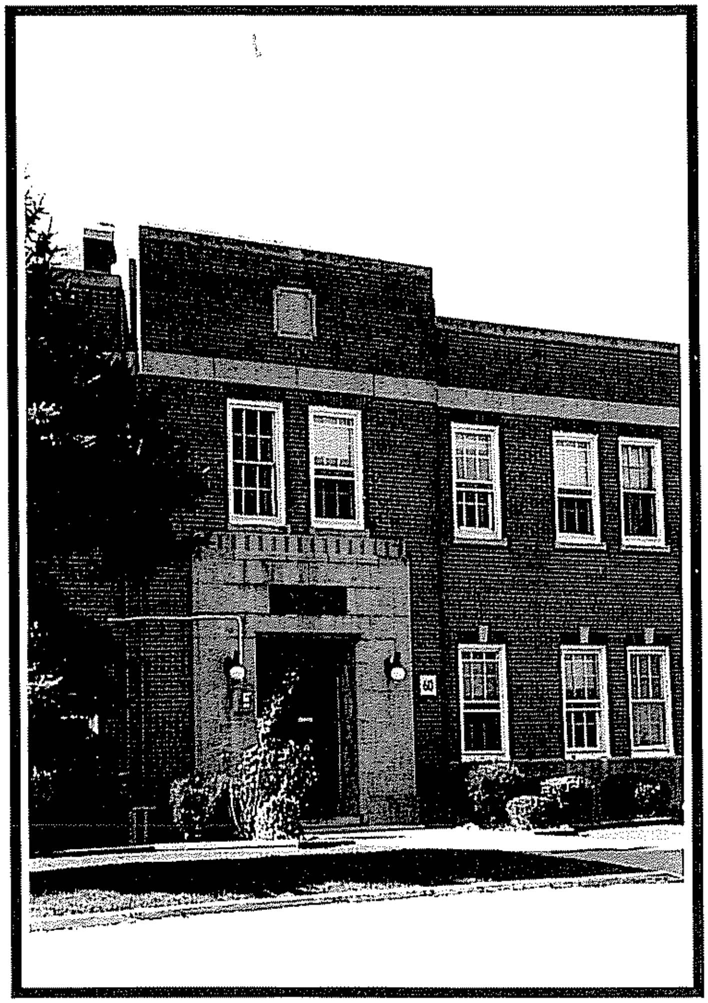


Figure 9. View of transmitter building (Building 5) at the Naval Radio Transmitter Facility (NRTF) Annapolis.



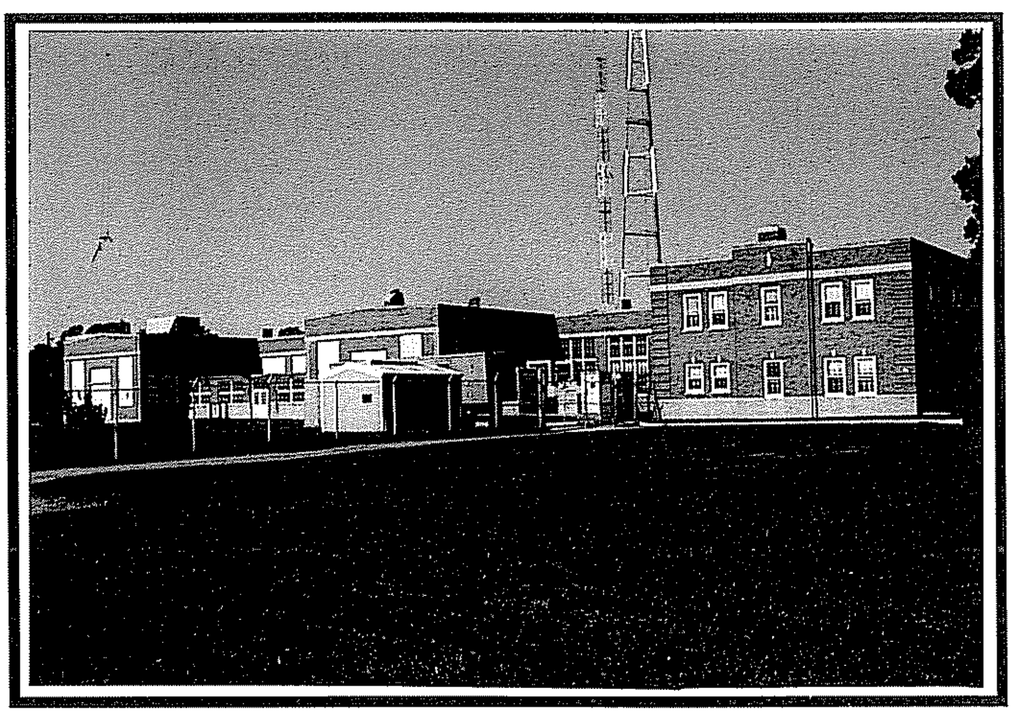


Figure 10. Above and below: View of transmitter building (Building 60) at NRTF Annapolis.

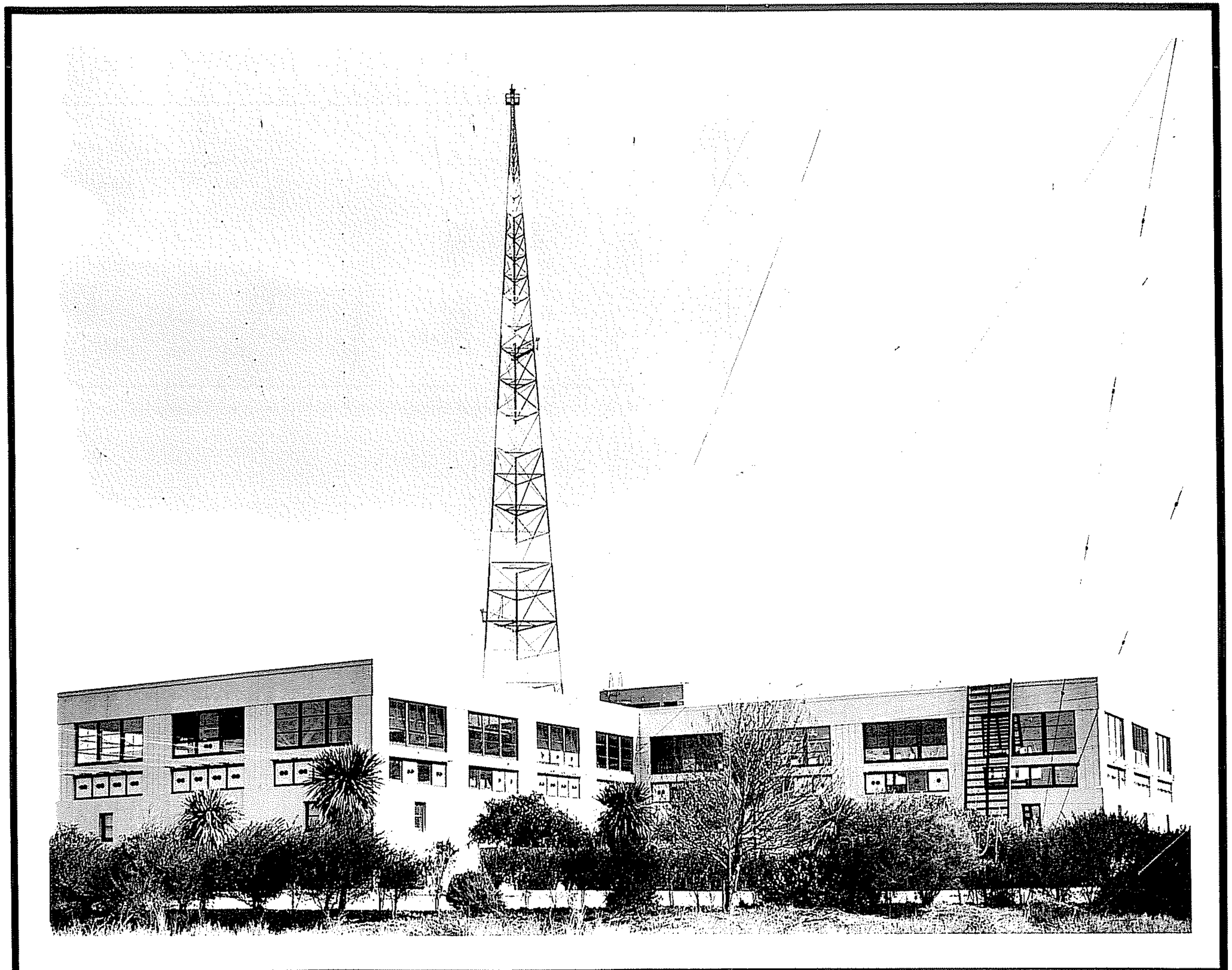


Figure 11. Historic photograph of the Communication Station at Mare Island, California, showing the high frequency (HF) transmitter building (Building 505) with tower in background, March 1949 (Courtesy of the National Archives and Records Administration, Still Photo Branch).

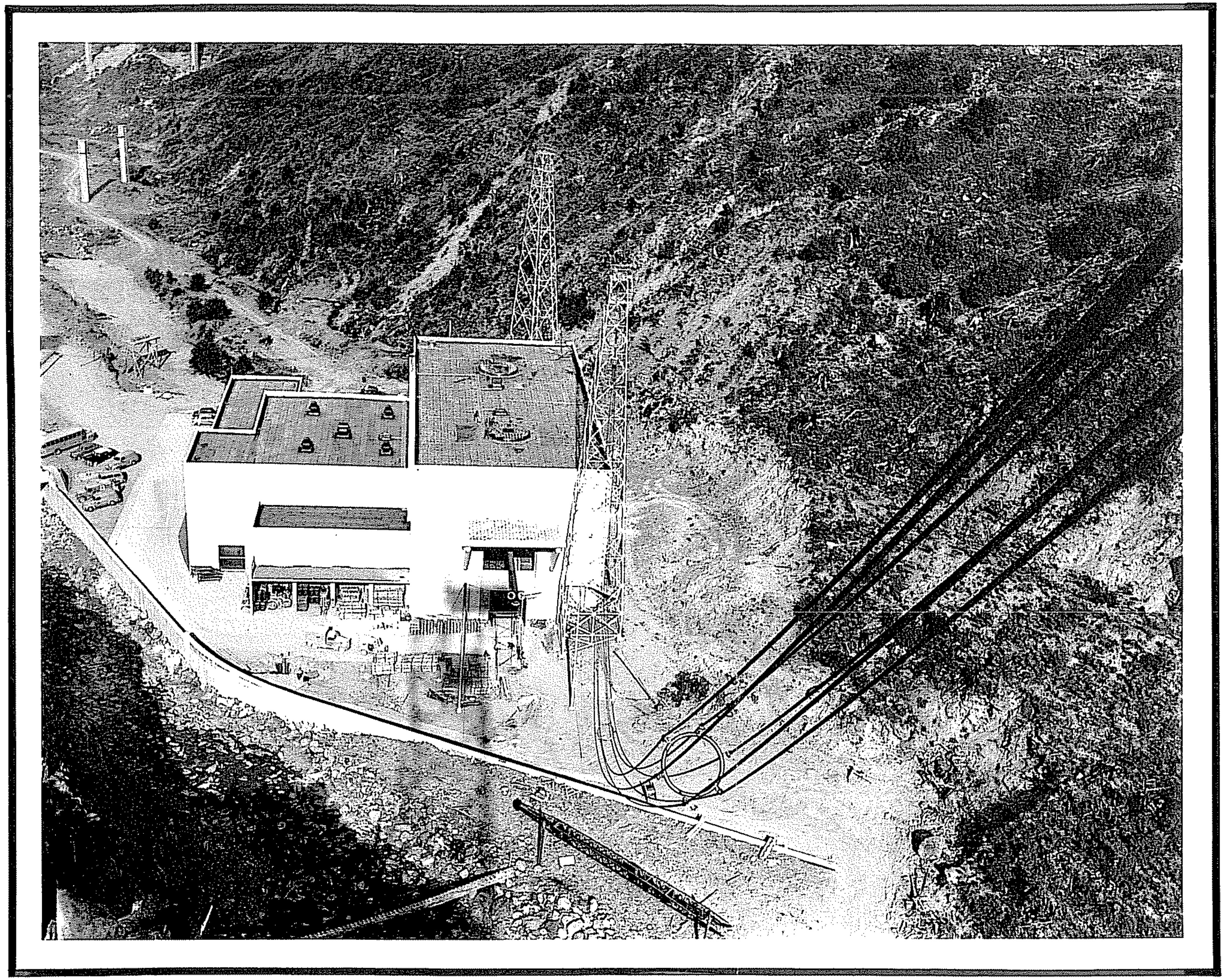
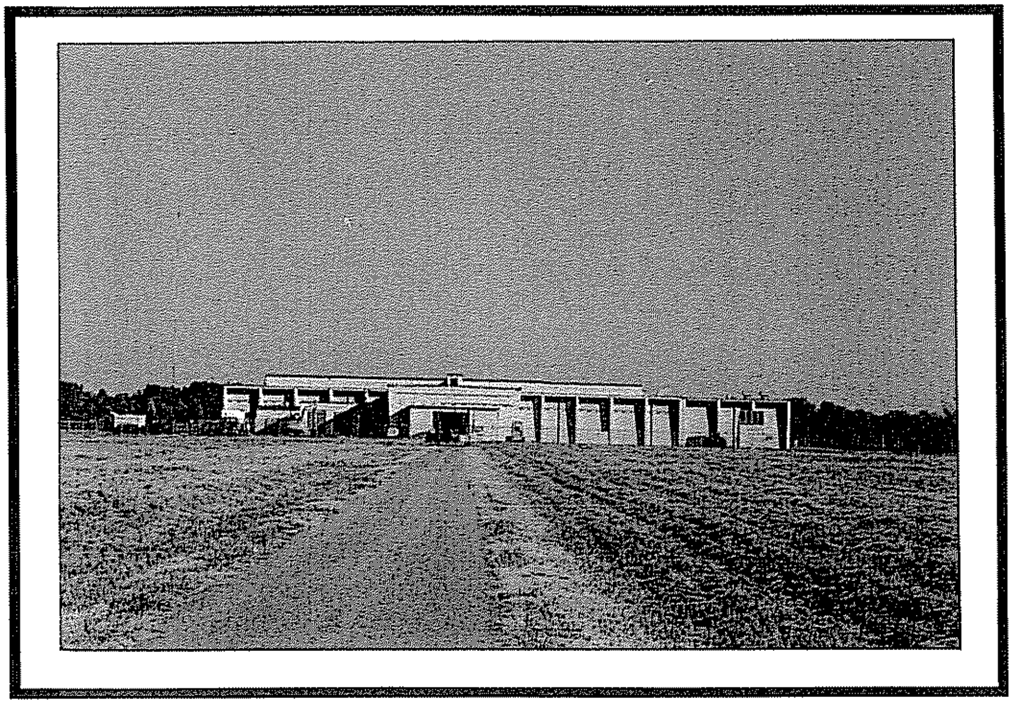


Figure 12 Historic photograph of the transmitter building at Jim Creek, Washington, one of the Navy's most powerful VLF transmitter facilities (Courtesy of the National Archives and Records Administration, Still Photo Branch)

Figure 13. Historic photograph of Naval Radio Station (T) Driver, Virginia, showing approach to transmitter building (Building D-10) with towers in background. The transmitter building was surrounded by an antenna field, September 1955 (Courtesy of the National Archives and Records Administration, Still Photo Branch)



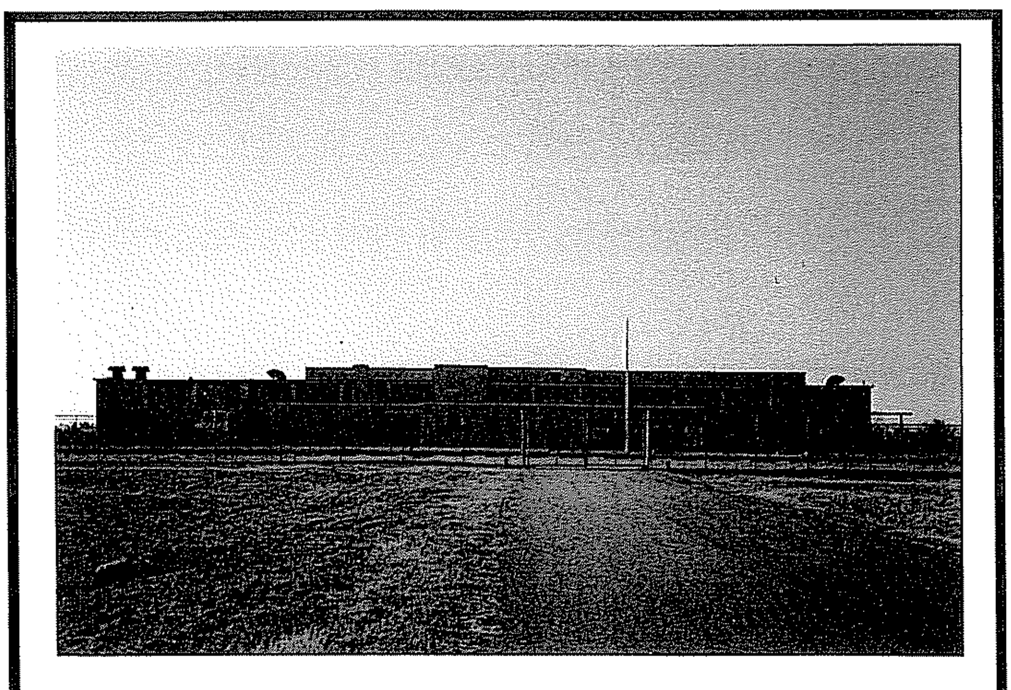


Figure 14 Above and Below: Front and rear view of operations building (Building D-10) at the Naval Radio Station (T) Driver, Virginia

Helix houses for 50-kw and higher LF antennas should be masonry and/or reinforced concrete construction (preferably reinforced concrete), with interior (floor, trenches, walls, and ceiling) completely copper lined. Entrances to helix houses must have double doors completely copper covered, of sizes permitting equipment installation. Linings (shieldings) should be 16-ounce copper sheets for LF antennas of the 50-kw type, and heavier (as determined by the Bureau of Ships) for antennas of higher power with continuous brazed or soldered joints.151

Both NRTF Annapolis and NRTF Driver contain examples of typical 1950s helix houses, which were designed to support 800-foot vertical radiator towers (Figure 18). Both structures were constructed as tall, one-story reinforced concrete buildings terminating in a flat, concrete slab roof. A set of double metal doors occupies the primary facade of each building, and coaxial cables extend from the rear end of the buildings and connect to the base of the antenna tower. NLFTF Aguada, Puerto Rico, provides a unique example of a Cold War-era helix house (Figure 19). Both the interior and exterior of Building 2902, including the floors, was constructed of aluminum. The interior housed the capacitors, which were used to tune the antenna. A wire conduit extended through the roof of the structure to connect to the 1,200-foot low-frequency antenna tower.

Support Buildings

A separate power source often was provided as part of the operations complex. Power houses are characterized by their low-scale and minimal ornamentation. A typical example of a power plant is found at NRTF Isabela. Building 3002 consists of a tall, one-story section with a ower wing along the north side. An overhead metal door is located on the primary (east) elevation. The only other openings on the building are louvered metal vents.

terminates in a concrete slab roof. The front, one-story portion of the building contained offices, the lunch room, and other employee support rooms. The rear, two-story, T-shaped portion was characterized by projecting concrete piers that divide the building into symmetrical bays. No window openings punctuated this section of the building. Loading docks were located at the north and west wings. The interior originally housed banks of transmitters and the basement was used to contain all the cabling.

The operations building (Building 2901) at the Naval Low Frequency Transmitter Facility (NLFTF) Aguada, Puerto Rico, is a two-story, L-shaped concrete structure terminating in a concrete slab roof (Figure 15). A lower, one-story section is incorporated into the elbow of the two-story core, resulting in a rectangular plan. The building contains no window openings; instead, louvered vents punctuate the first and second floor openings. All of the original equipment, including the transmitter, was removed from the building during the 1970s and replaced with state-of-the-art equipment. Currently, Building 2901 contains a circa 1980s transmitter and a circa 1995 Solid State transmitter.148

NRTF Isabela provides an example of a larger-scale operations building. The Isabela site is used as a "test bed" for all communications systems employed by the Navy.149 The operations building (Building 3001) employs concrete construction and terminates in a flat roof. A concrete canopy extends along the upper wall surface of the building's exterior to shade the window openings. Building 3001 adopts a cruciform plan formed by a tall, two-story central tower with four wings radiating from the tower. The main wing extends from the south side of the tower and consists of a taller, two-story wing. A set of double metal doors, located at the south end of the wing, provides access to this section. The other three wings are only one-story in height.

Helix Houses

Transmitting antennas of the low frequency type require electronic tuning devices, including coils (helices) and variometers. For high power LF or VLF transmitting antennas (50 kw or higher), the tuning equipment was installed in a helix house. In general, the helix house was sited near or at the base of the associated antenna system.150 The building's interior consisted of an open space whose walls, floor, and ceiling were covered in aluminum sheets.

NRTF Annapolis contains an example of an early helix house constructed in 1935. The helix house (Building 5A) was designed as a tall, one-story brick building terminating in a flat roof with parapet (Figures 16 and 17). A recessed central block flanked by projecting brick piers defines the front and rear elevations of the building. A set of double metal doors served as the main entrance. As originally designed, the building contained a large opening along the east elevation, which allowed for the transmitter cables to extend from the building's interior to the adjacent transmitter tower. This opening was infilled subsequently with corrugated metal sheathing, and the cables were redirected through an octagonal opening in the building's roof. The transmitter cables extend from the helix house to a lower metal tower directly east of the building. The cables then extend to three different points along the main 1,200-foot transmitter tower. The interior of Building 5A was designed to accommodate two 15-foot tuners; the original tuners have been replaced with newer equipment. The floor is covered with steel plates, and the interior foundation is grounded by a metal strip that extends along the entire perimeter.

NRTF Annapolis also contains two representative World War II-era LF helix houses Buildings 68 and 69 were built in 1942 to service the LF "Marconi Triatic" antenna. These helix houses were designed as one story, brick structures terminating in a flat roof.

In 1950, the Bureau of Yards and Docks established the following design criteria for helix houses:

Figure 15. View of operations building (Building 2901) at the Naval Low Frequency Transmitter Facility (NLFTF) Aguada, Puerto Rico.

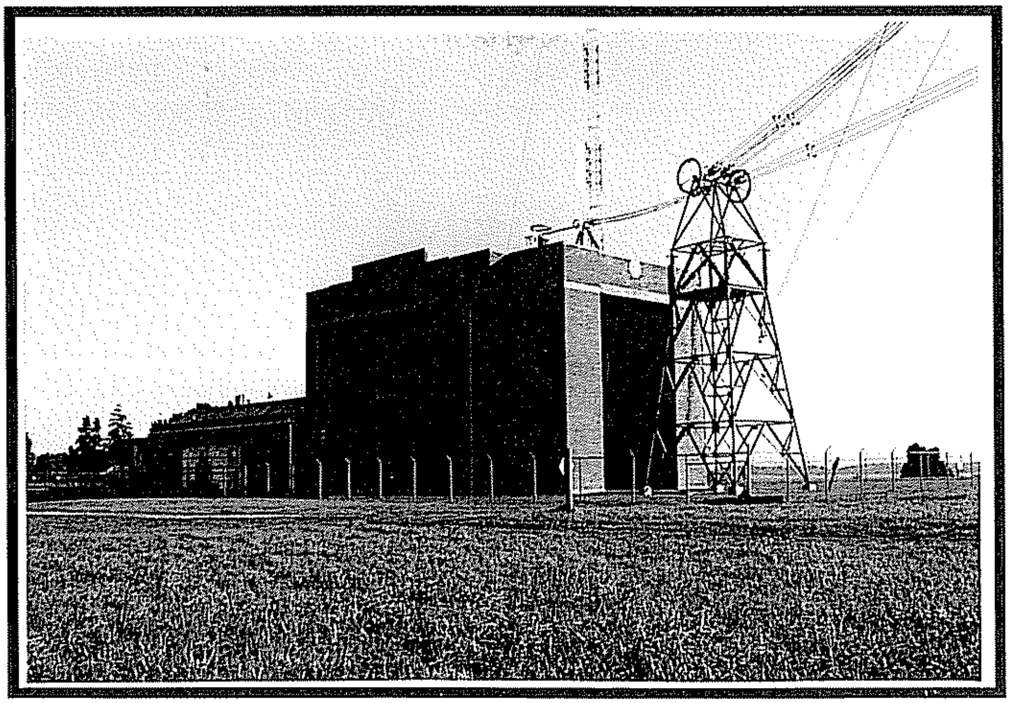


Figure 16. View of helix house (Building 5A) at NRTF Annapolis. The helix house was constructed to support the VLF antenna array.

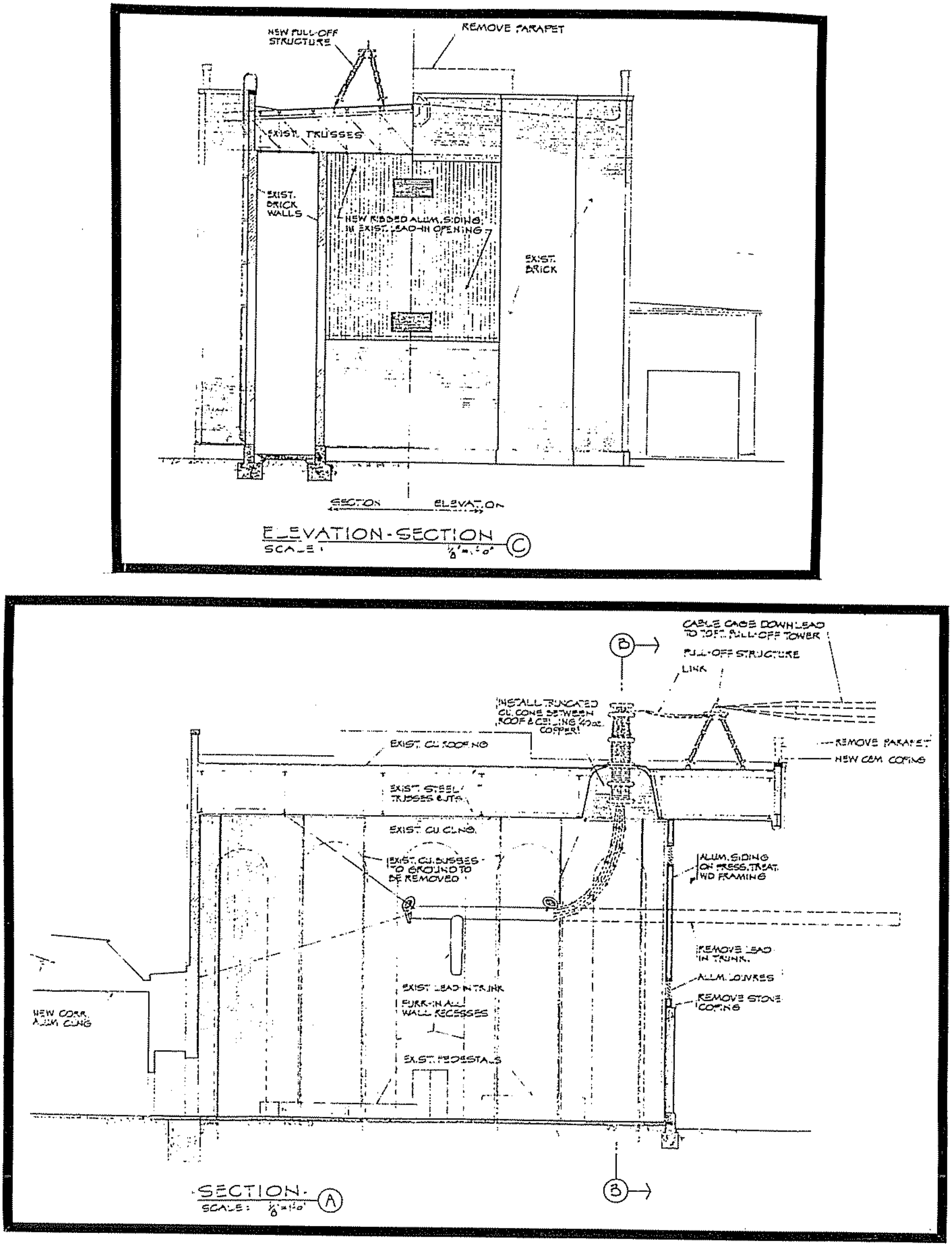


Figure 17. Sections of helix house (Building 5A) at NRTF Annapolis (Courtesy of NRTF Annapolis).

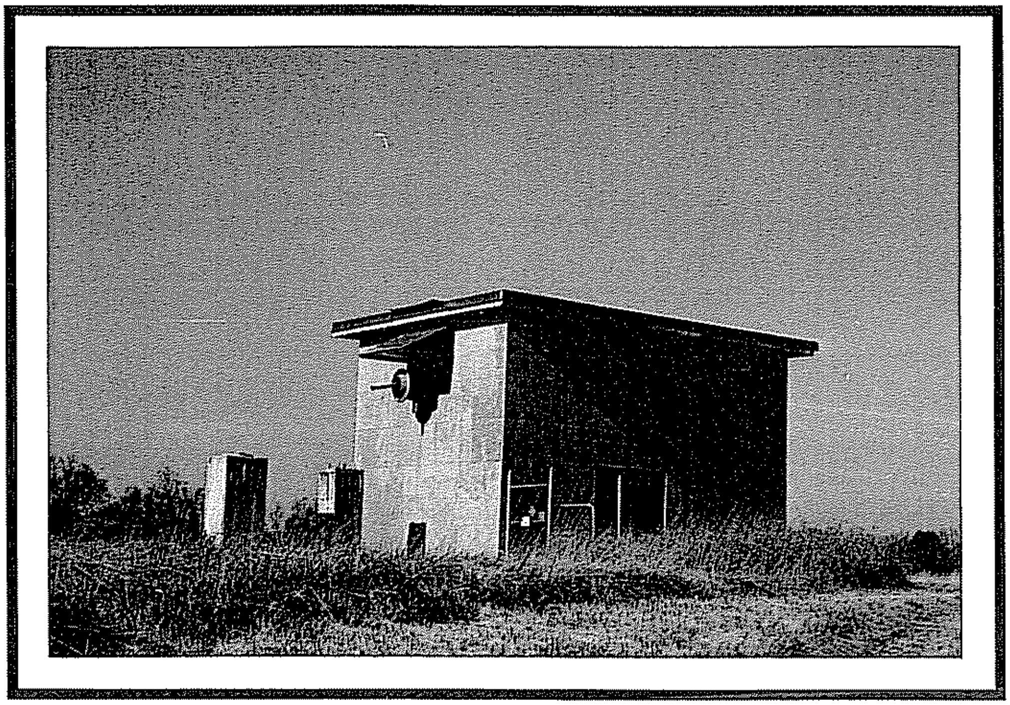


Figure 18. View of a typical 1950s helix house. Building D-11 was constructed at NRTF Driver to support an 800-foot vertical radiator tower.

Figure 19. View of helix house (Building 2902) at NLFTF Aguada, Puerto Rico.

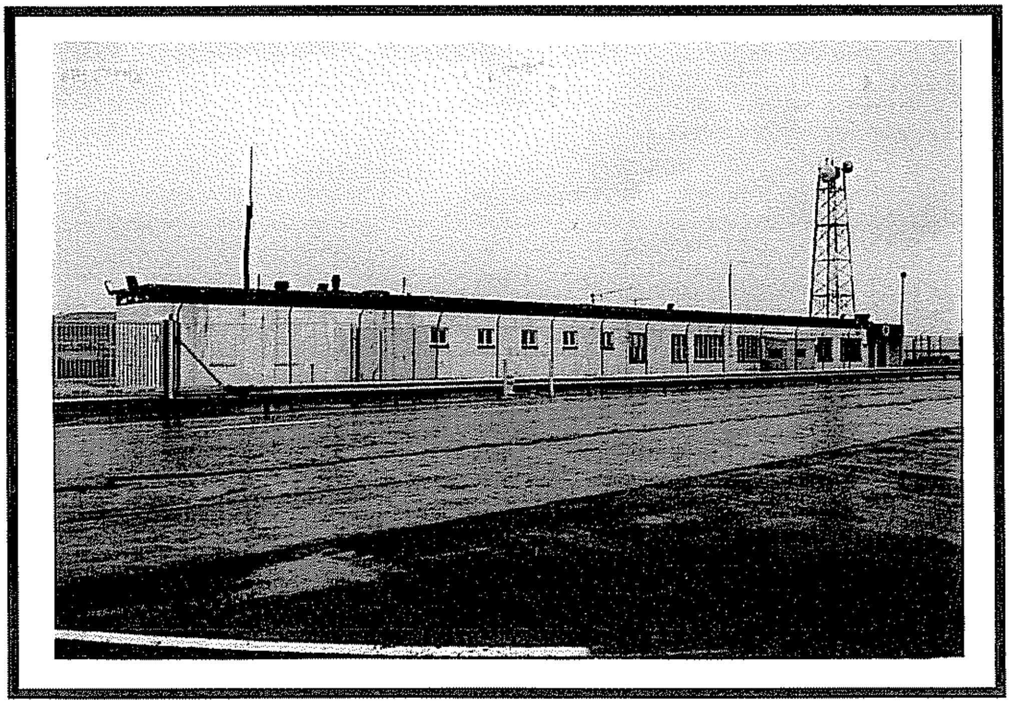


Figure 20. Communications center (Building 839) at Naval Air Station (NAS) Keflavik. The building is typical of the 1950s general design policy for operations buildings.

COMMUNICATION CENTERS

Introduction

The purpose of a communication center is to receive, transmit, and deliver messages. Communication centers typically are sited within existing naval bases.152

Evolution of Communication Centers

By the 1950s, the design of the communication center had become fairly standardized. A typical communication center contained a message center, a cryptographic section, and transmitting and receiving facilities. The communication center could contain all these facilities in one place, or transmitting and receiving facilities could be separated from the communication center.153 In 1953, the Bureau of Yards and Docks issued a publication outlining the general design policy for radio communications facilities:

Because uninterrupted communications must be maintained, particularly in emergencies, it is the policy of the Bureau to design communication facilities that are functional to the highest degree; this requires construction that is of permanent type, and blast- and splinter-resistant whenever possible. Masonry and/or reinforced concrete construction is generally used, the end results being windowless buildings with mechanical ventilation or air conditioning.154

With the introduction of satellite communications during the 1970s, a new type of communications facility was developed. Satellite communications (SATCOM) earth terminals were located in remote areas to minimize interference to the satellite. These terminals were linked via telephone cables or microwave radio links. SATCOM earth terminals consisted of a single, large antenna; a receiver and transmitter; multiplex equipment; modulating-demodulating equipment; and telemetry equipment.155

Associated Property Types

Terminal Equipment (TE) Buildings

The major property type associated with the Navy's communication centers is the operations, or terminal equipment (TE) building. TE buildings generally included control and terminal equipment facilities and, in some cases, a communication center. TE buildings typically were separated a minimum of one and one-half miles from a radio receiving facility since they contained electronic equipment that caused radio interference.156 The interior floors of these buildings were reinforced concrete or structural steel framing with cellular steel flooring. The first floor of the TE building contained space for offices, radio and relay room, cryptoroom, receiving room, main frame room, and storage. The second floor included space for a control (frame) room, mail room, duplicating, electronics testing room, code room, vault, equipment area, communications, administration, and storage.157

An example of a typical operations building is the communications center (Building 839) at the Naval Air Station (NAS) Keflavik, Iceland. Building 839 was built in 1954 to serve as the operations center for the U.S. Naval Communication Station (NAVCOMSTA). The operations building is supported by a receiver and transmitter site, and three remote sites (Dye-5, H-1, and H-3). The building was designed as a one-story, irregular shaped concrete structure terminating in a flat, concrete slab roof (Figure 20). The front elevation contains a row of metal-sash windows. A 70-foot tall microwave tower was installed at one end of the building.

Satellite Communications (SATCOM) Earth Terminals

Satellite communications (SATCOM) earth terminals were established during the 1970s as a new type of communications center These facilities provided ground links with the Navy's satellite communications network. A representative example of a SATCOM earth terminal building (Building 257) was constructed at Northwest in 1972. Building 257 was designed as a NATO facility to link all of the member NATO capitals, headquarters, and major commands. The facility represented one of twelve satellite ground terminal members of the NATO Integrated Communications System.158

Building 257 was constructed as a one-story, poured concrete structure terminating in a flat roof (Figure 21). A geodesic dome dominates the roof of the building, which protects the delicate antenna equipment. The main entrance is defined by a recessed entrance capped by a projecting concrete canopy. A raised concrete platform extends along the front elevation; overhead metal doors and single door openings are aligned along the wall surface.

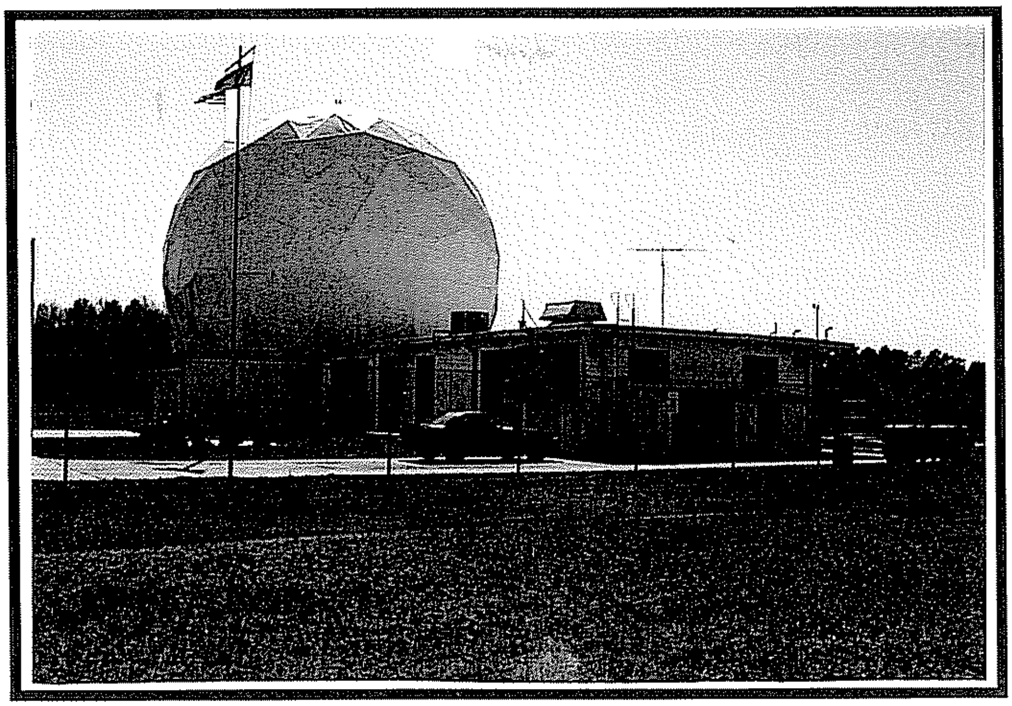


Figure 21. View of the NATO SATCOM Ground Terminal (Building 257) at NSGA Northwest

DIRECTION FINDER (D/F) STATIONS

Introduction

Radio direction finder (D/F) stations are an important and vital component of the Naval Communications System. The primary mission of a D/F station is to determine the position of ships at sea or to pinpoint the precise location of transmitted radio signals. D/F stations only function in the receiving mode. Often, they are provided with transmitting equipment of limited range to transmit results of observations to ships requesting bearings. Such a system is highly effective in search and rescue efforts; anti-submarine warfare (ASW); and, locating and monitoring enemy transmissions.159

D/F stations typically are sited along coasts and at harbor entrances to provide good bearing intersections to vessels in adjacent waters. In order to track the location of a transmitted signal, a control center instructs two or more D/F facilities to take a fix (true bearing) on a radio signal of a certain frequency and located in a definite sector. Each D/F facility reports back its fix to the control center; these coordinates are then plotted. The point of intersection indicates the source of the questionable signal.160

Evolution of D/F Stations

In 1916, the Navy initiated construction on a chain of permanent direction finder (D/F) stations along the Atlantic coast to detect enemy signals. The D/F stations were anticipated to be critical in the event that the U.S. became involved in a war. England had established D/F shore systems by this date, and used this network to track German ships and submarines. Upon the U.S. entry into World War I, the Navy had completed three D/F stations around the seaward approaches to the important harbor of Brest, France. These stations proved vital to tracking German submarine positions.161

Stations were constructed around the approaches to the harbors of Boston, New York, and Charleston, and at the entrances of the Delaware River and the Chesapeake Bay. Many of these sites were intended to serve as navigational aids for Navy and troop ships returning from overseas. The D/F stations were arranged in groups comprising a "master" station and two "slave" stations. The master station controlled a transmitter at a distant station by landline. The two "slave" stations telegraphed bearings to the master station, which then plotted the position fixes. The fixes, or bearings, were then transmitted to the convoy commander using an associated radio transmitting station remotely controlled from the master station. By the end of World War I, these D/F stations were nearing completion. Their successful operation resulted in the establishment of groups of D/F stations at all important ports in the United States, on the Great Lakes, and at dangerous navigational points along the coast. By 1923, a total of 46 D/F stations were installed along the Atlantic, Gulf, and Pacific coasts.162 The Navy's D/F network "became indispensable to the Navy and the shipping of the world".163

During the mid-1930s, the Navy installed a series of newly-developed high-frequency D/F systems along the Atlantic and Pacific coasts and in Oahu, Hawaii. By World War II, this chain extended from Iceland to the middle of South America. During World War II, the Navy's shore and ship D/F systems played an important role in defeating the German submarine menace.164

By the 1950s, D/F stations became a well-established facet of the Navy's shore communications system. A typical 1950s D/F station consisted of two distinct components separated by approximately three and one-half miles. One area was designated the operations area and the other was the logistic, or transmitter area. The operations area encompassed approximately 180 acres, which contained the operations building and its associated antenna arrays; the auxiliary power building; and, rhombic receiving antennas. Four independent direction finders, and their associated antenna array, were placed within a minimum radius of 100 yards from the center of the operations building. The logistic area consisted of roughly 60 acres containing barracks and mess hall; transmitting rhombic antennas; and support buildings (i.e., power plant, storage, garage, workshop).165

Associated Property Types

Antenna Array

D/F systems utilized by the Navy underwent a number of improvements during the 1950s and 1960s, with older, obsolete systems getting replaced by newer, state-of-the-art systems. The section on Shore-Based Communication Systems provides a more-detailed discussion of the evolution of the Navy's D/F systems.

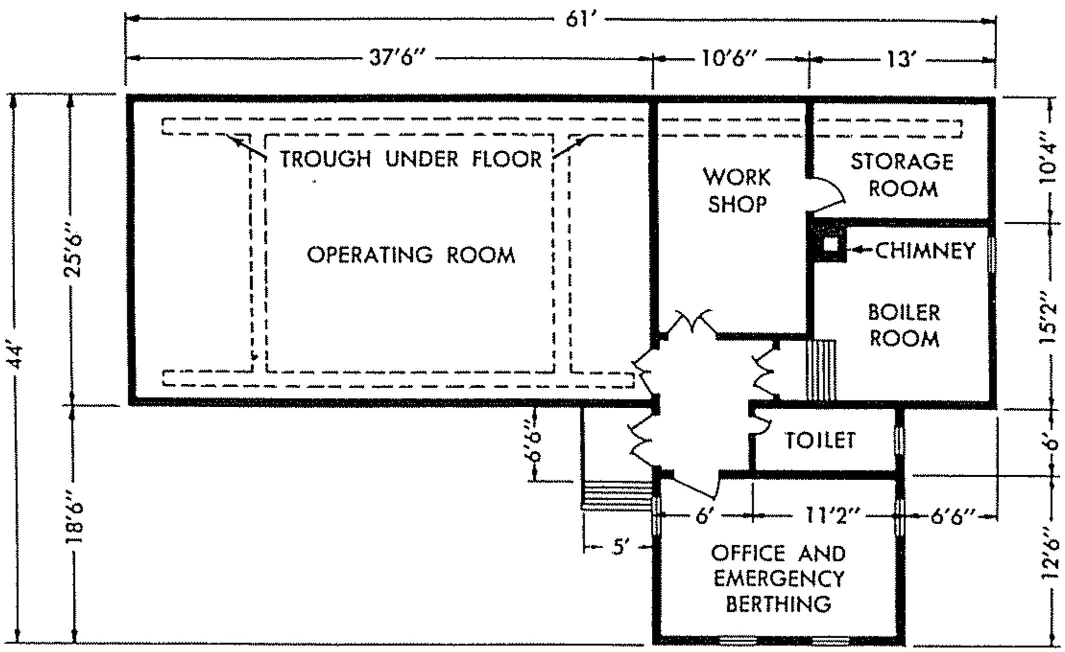
Operations Building

A typical 1950s D/F operations building consisted of a permanent, one-story, steel-frame or masonry structure. Typically, the building was characterized as a rectangular, gable-roofed structure with a wing extension to one side (Figure 22). The main rectangular block measured 25-1/2 feet by 61 feet and contained the operations room, workshop, storage room, and boiler room. The side wing measured 18 feet by 18-1/2 feet and housed the toilet, office and emergency berthing, and the entrance passage.166

Building 41 at Northwest provides an example of a ca. 1960 operations building constructed to support the "Wullenweber" Circularly Disposed Antenna Array (CDAA) system. The operations building, which housed all the electronic equipment for directing the beams and conducting monitoring and direction-finding activities, was designed as a two-story, brick, windowless building (Figure 23). Four concentric antenna arrays surrounded the operations building. Underground electrical cables connected the antenna array to the operations building. The interior plan of Building 41 included space for operations, communications, and administration departments; offices; the Special Communications (SPECOM) Operations Maintenance department; and a training area (Figure 24). Building 41 has grown over the years to accommodate its expanding mission. This is evidenced by several additions and extensive interior modifications. A similar operations building was constructed at Sabana Seca, Puerto Rico, and Winter Harbor, Maine, as part of its CDAA system. The Winter Harbor operations building (Building 85) has undergone minimal exterior changes and alterations to its interior layout, making it one of the most intact examples of a CDAA operations buildings.

Antenna Maintenance Shop

A number of the CDAA complexes established at NSGA facilities include an antenna maintenance shop. These buildings contained space for work stations and spare parts storage. Maintenance shops generally consisted of a small, one-story prefabricated metal structure.



D/F Operations Building—Floor Plan

Figure 22. Typical 1950s D/F operations building showing floor plan layout (United States Navy, Bureau of Yards and Docks, *Radio Communications Facilities, Shore Based*, 26).

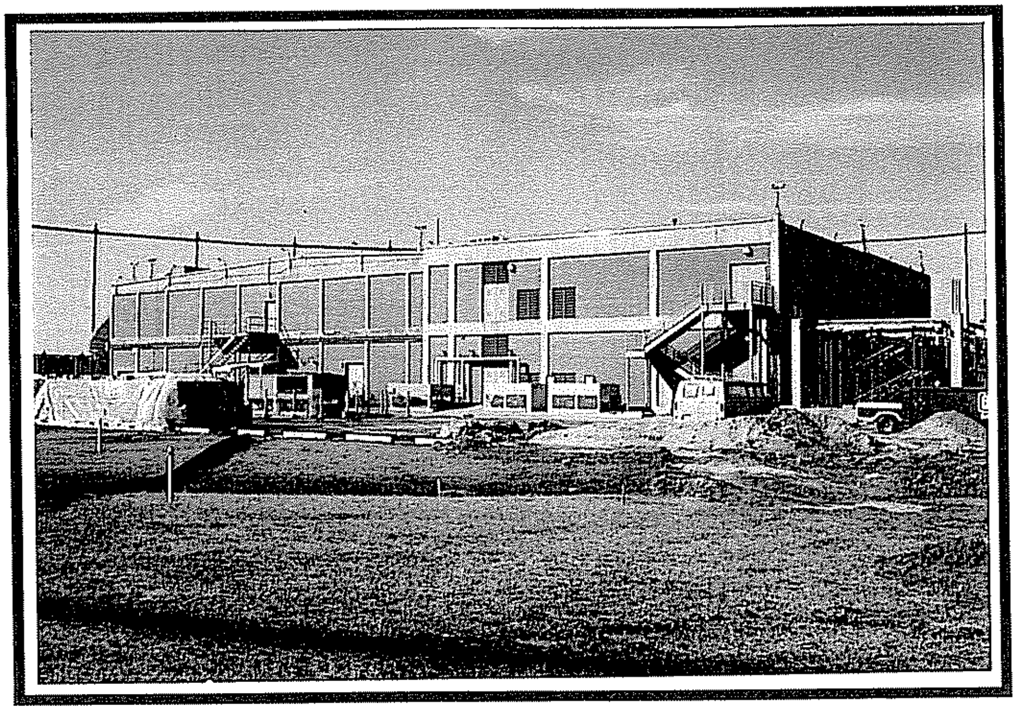


Figure 23. View of CDAA operations building (Building 41) at NSGA Northwest, Virginia. Building 41 was designed as a two-story, brick, windowless building situated at the center of four concentric antenna arrays.

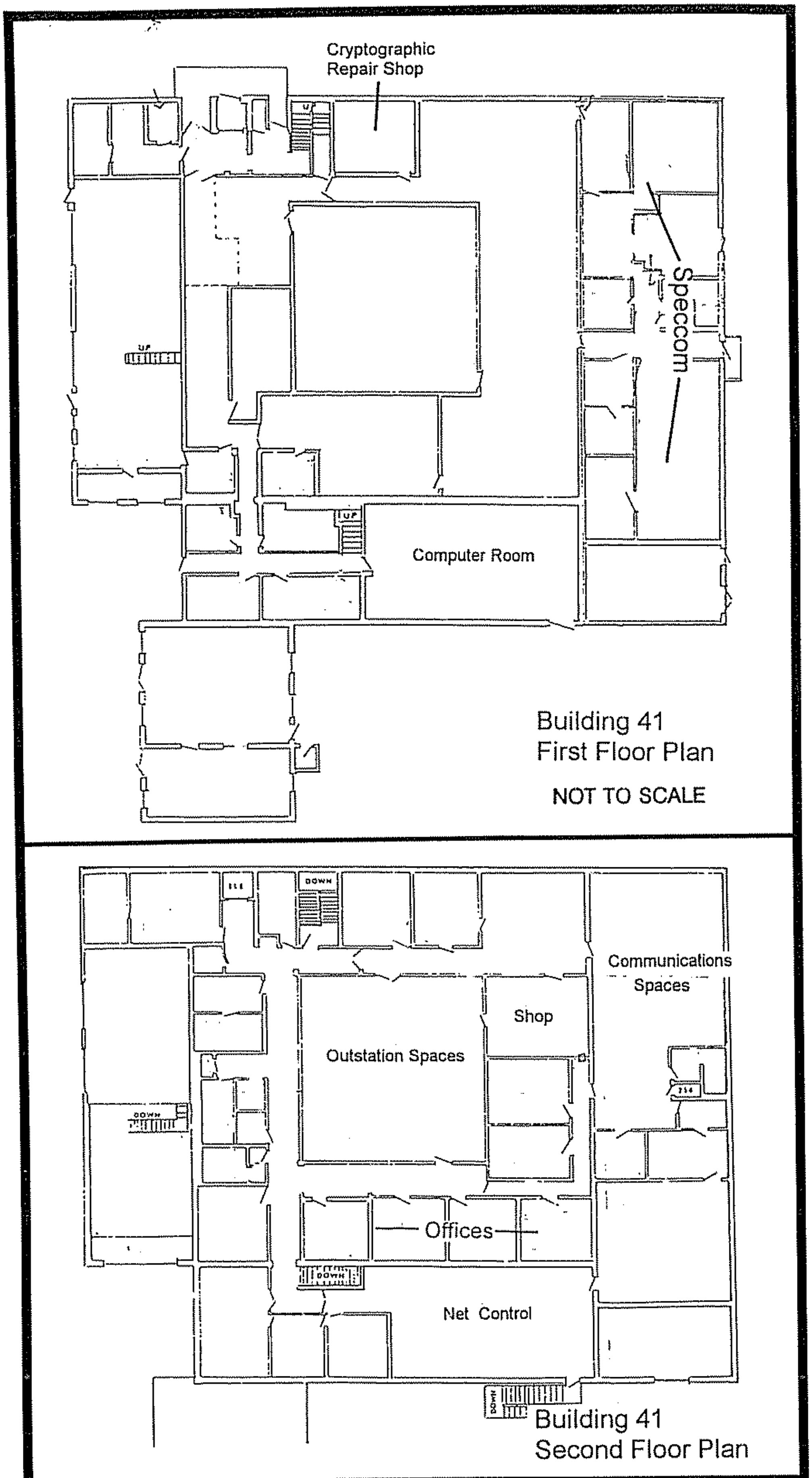


Figure 24. Above and below: First and second floor plans of operations building (Building 41) at NSGA Northwest (Courtesy of Operational Archives, Navy Historical Center).

SHORE-BASED COMMUNICATION AND SURVEILLANCE SYSTEMS

Surveillance methods used by Signals Intelligence (SIGINT) have undergone minimal change since the 1940s. By 1945, many components of current SIGINT technology had been developed, including automated frequency search devices, signal direction finding (D/F) systems, and cryptography. Major changes, however, had occurred in terms of the technological capability of the communications systems. In many cases, advancements in technology resulted in smaller, more efficient systems and substantially increased capabilities.167

Classification of the Navy's Communications Systems

The U.S. Navy's inventory of shore-based communications and surveillance systems can be classified according to function. Military communication electronic equipment is designated by the "AN" nomenclature system. The letters AN are followed by a slant bar and three additional letters (i.e., AN/GPS-56). These letters indicate where the equipment is to be installed (aircraft, missile, ship), the type of equipment (radar, countermeasures), and the purpose of the equipment (weapon control, navigation, detection). For example, the first letter for shore-based communication systems may consist of a "G" indicating a ground-type installation. The second letter may include "P" for radar or "R" for radio indicating the type of equipment. The third letter may include "C" for communications, "D" for direction finder, "R" for receiving/passive detection, "S" for detection and/or range bearing, or "T" for transmitting.168

This section organizes the Navy's shore-based communications and surveillance systems according to the following categories:

- Search radars
- Direction finders (D/F)
- Tropospheric scatter systems
- ELF/VLF/LF systems
- HF systems
- VHF/UHF/SHF systems
- Satellite systems

The MF spectrum is not included in the above-mentioned categories since it is primarily used for commercial purposes and, therefore, largely useless for military applications. The MF band includes the international distress frequencies and, as a result, some ships employ MF communications equipment for this purpose. MF equipment at shore installations is used primarily for search-and-rescue operations.169

The following division presents an overview of the evolution of the different systems, and its major advantages and limitations. Appendix B should be referenced for a more comprehensive listing of the Navy's communications systems. The appendix follows the same categorization presented above, and summarizes the system's period of use; technological developments; and function.

Strategic Versus Tactical Systems

Communications systems are used for both strategic and tactical purposes. Strategic communications generally are worldwide in nature, and are employed to monitor enemy communications and to collect passive electronic intelligence (ELINT). This latter function includes searching, intercepting, locating, recording, and analyzing intercepted transmissions. The interception of enemy communications at the strategic level provides intelligence information on enemy capabilities, operations, and plans. Strategic systems generally require the use of large, complex, and permanent fixed antennas and sites. Direction finder (D/F) systems, which are used to pinpoint the location of an enemy signal, and radar systems fall into this category. Tactical systems, on the other hand, provide immediate operational data. Tactical systems typically are employed in, or in close proximity to, combat operations areas. This report is concerned with Navy communications and surveillance systems, and does not include a discussion of tactical systems.170

The Navy's Frequency Spectrum

A major characteristic of electromagnetic energy is frequency, or how often complete energy waves pass a point. The frequency of a transmission is measured by the number of oscillations per second; the unit of measure based on the "Herz". For example, one Kiloherz (KHz) is one thousand cycles per second and one Megaherz (MHz) is one million cycles per second. A second important characteristic of radio transmissions is wavelength, which is the distance between a point on one wave and the same point on the next wave. As frequency rises, the wavelength shortens and the radio path approaches a straight line. Correspondingly, lower frequencies exhibit longer wavelengths. Frequency and wavelength are important characteristics of electromagnetic energy since they determine the distance such energy can travel in the atmosphere and whether it can go around corners or penetrate water.171

Each frequency and wavelength can be classified in the electromagnetic spectrum, which ranges from extremely low frequency (ELF) to extremely high frequency (EHF). Figure 25 illustrates the radio frequency bands and their designations. Although the basic principles are the same for all frequency ranges, each frequency region has its own particular characteristics that make it suitable for certain applications. For example, systems operating in the ELF, VLF, and LF ranges are used primarily for communications with ships and submarines Lower frequency bands are more appropriate for this application since these electromagnetic waves can easily penetrate water. The MF range is of minimal importance to military applications, and is used primarily for commercial communications. The HF range represents the primary mode of military communications. However, HF systems have been supplanted by satellite communications. The radio-frequency or radiowave region, from VHF to SHF, is used primarily for aircraft communications, as well as radar, radar jamming, radio communications, and radio-interception equipment.172

Rapid growth in the number and complexity of communications systems have placed increased demands upon the radio frequency spectrum due to the potential for signal interference from systems operating within the same band. These demands include both civilian and military applications, such as communications, location and ranging, and industrial and scientific uses.

The Commander Naval Telecommunications Command (NAVTELCOM) was charged with the responsibility of managing the Navy's use of the radio frequency spectrum. The military relies on nine bands of the radio frequency spectrum, ranging from ELF to EHF. These are discussed in greater detail in the following sections.173

Radio Wave Propagation

Four primary methods are used to propagate electromagnetic energy waves. These include line of sight; ground wave path; waveguide path; and sky wave path. Line of sight, the most common method of propagation, refers to electromagnetic signals that travel straight from the transmitter to the receiver. Signals travelling by line of sight are relatively short-ranged and can be blocked by obstacles, such as hills.174

Another type of propagation is the ground wave path. These signals are capable of travelling through the earth's surface. This method of propagation relies on two different types

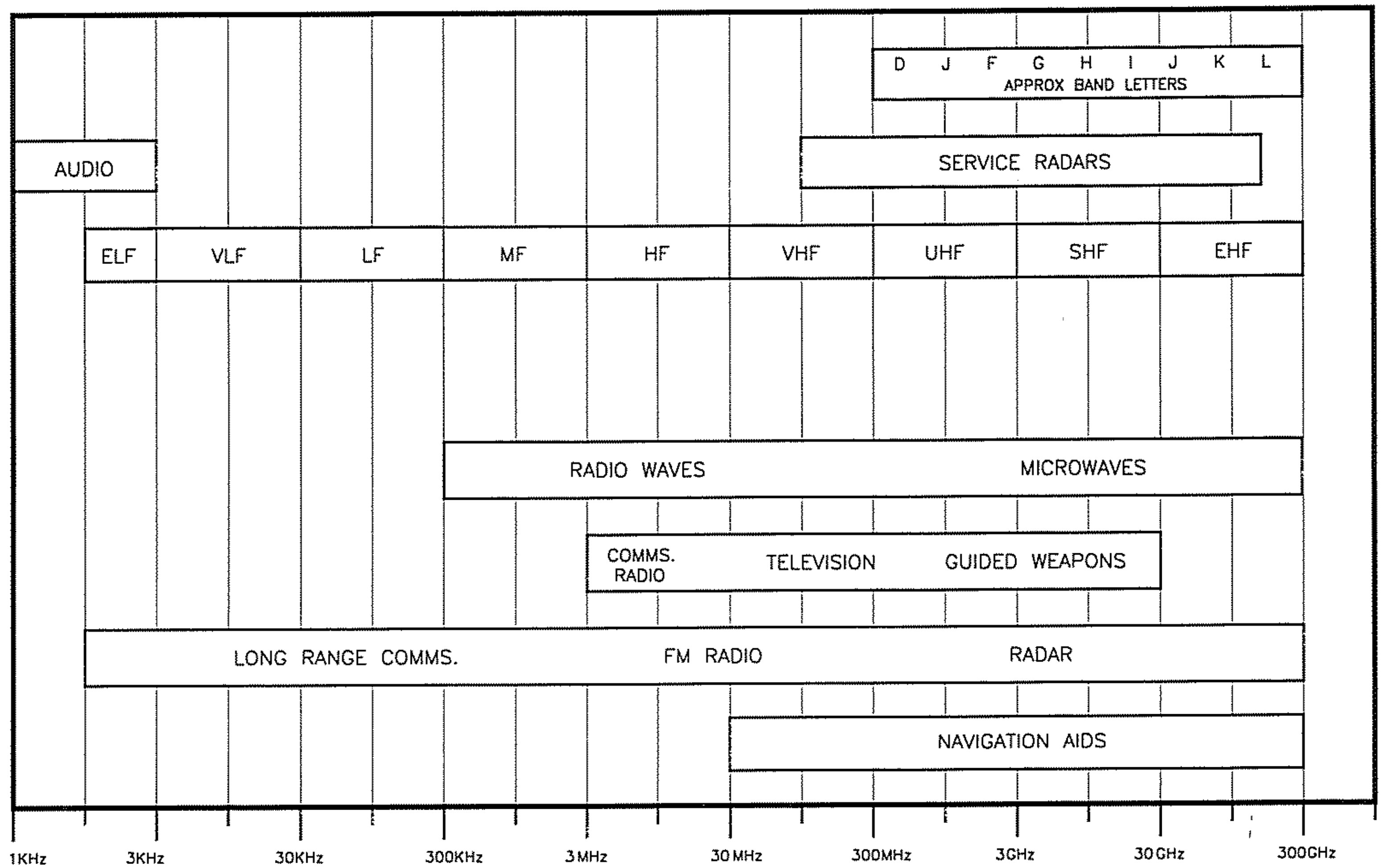


Figure 25. Diagram showing the frequency bands and their designations (Derived from William Kennedy, *Intelligence Warfare: Today's Advanced Technology Conflict*, 82).

of energy waves, the ground wave and sky wave. When a radio wave leaves a vertical antenna, a part of the wave moves outward in contact with the ground to form the ground wave; the rest of the energy wave moves upward and outward to form the sky wave (Figure 26). Both signals provide different methods for sending messages from transmitters to receivers. Ground wave propagation normally is used for relatively short-range communications. Ground waves, however, sometimes are utilized for long-range communications on VLF or LF using very high power.175

The third type of propagation is the waveguide path, in which signals are channelled between outer space and the earth's surface using the earth's ionosphere. The ionosphere is a layer of electronically charged air located approximately 40 to 350 miles above the earth, which has the ability to absorb, reflect, or divert various types of signals. For example, very long wavelength signals transmitted by LF radios are contained within the earth's atmosphere by the ionosphere, allowing them to be transmitted great distances by waveguide path.176

The fourth type of propagation is the sky wave path, in which radio signals are bounced back and forth between to the earth's surface and the ionosphere (Figure 27). The ability of the ionosphere to return a radio wave to earth depends on a number of variables, including the angle at which the sky wave hits the ionosphere, the frequency of the transmission, and upon the ion density. As the frequency decreases, the critical angle increases. Low frequency fields can be projected straight upward and will be returned to earth.177

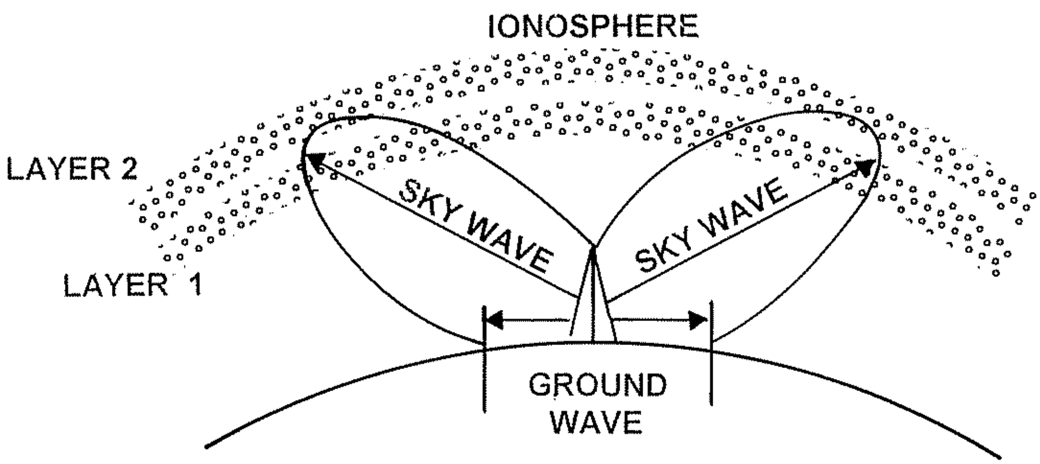


Figure 26. Diagram illustrating the formation of the ground wave path (United States Navy, Bureau of Naval Personnel, *General Communications*, 19).

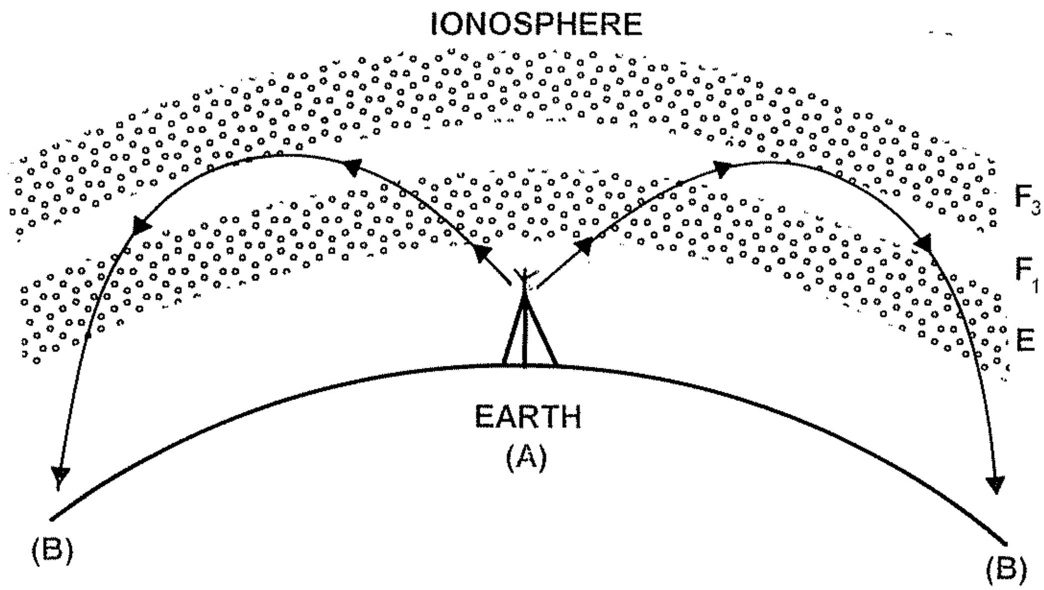


Figure 27. Diagram showing the refraction of the sky wave by the ionosphere (United States Navy, Bureau of Naval Personnel, *General Communications*, 21).

SEARCH RADARS

Introduction

Radar (Radio Detection and Ranging) is an electromagnetic device that is capable of detecting the location of objects, such as aircraft, ships, satellites, and the natural environment. The main advantages of radar are the ability to detect a target at great distances and to locate its position with relatively high accuracy. Radars have been used for a variety of military applications, including detection (i.e., aircraft, ships, surface vehicles, and personnel); air traffic control; aircraft navigation and landing aids; weather observation; and extraterrestrial observation.[178]

Radar measures range, or distance, and angular location. Radar operates by generating signals, in the form of bursts of radio frequency energy, into space using a transmitter antenna. When the radio pulse strikes an object in its path, it returns as an "echo" from which the direction, range, and character (i.e., ship, submarine, airplane) of the object can be determined. The receiver picks up, or receives, the echoes of the preceding pulse from objects in the beam path. The function of the receiver is to amplify the echoes of the radar transmission and to filter them to extract maximum data.[179] In most cases, the transmitter and receiver are collocated and utilize a common scanning antenna. A "duplexer" is used to enable a single antenna to function in the transmitting and receiving mode. Some long-range surveillance radars employ widely separated "bistatic" antennas, which achieve better resolution by triangulation.[180]

Radar systems are used primarily by the military for tactical purposes, and are not used for communications. Ground-based radar systems can be used for both air and ground surveillance and detection; target-acquisition and tracking; range instrumentation; and air traffic control. This report only addresses the Navy's shore-based surveillance, or search, radars.

Search radars are designed to continuously scan the horizon to provide early warning of hostile targets, such as air, missile, and space attacks. Track radars are then used to provide more-detailed data (i.e., range, bearing, and elevation) on identified targets. Large, ground-based radars also are used to search and track satellites. Surveillance systems typically consist of an interlocking chain of radars sited along a defended perimeter. Phased array radars and over-the-horizon (OTH) radars represent two types of surveillance systems employed by the Navy.[181]

Evolution of Search Radars

The exploitation of radar arose from military needs during World War II to detect and locate aircraft, ships, and other targets. Before the invention of radar, airborne objects were located by radiogoniometry, or "direction finding", using angular bearings. This method located an object by plotting the angles on a map of relative bearings. The major disadvantage of this system was that it could only be used to locate "friendly" targets, or those sending out an active signal.[182]

Early experimentation with radar by the United States was initiated during the 1920s and was prompted by military needs for better surveillance and navigational aids, as well as weapon control. Dr. A. Hoyt Taylor and Leo C. Young are recognized as "radar pioneers" due to their experiments at the Naval Research and Aeronautical Laboratory in 1922, when they observed radio-echo signals from moving objects. This discovery formed the basic principle of radar.[183] Most of the early research on radar was conducted in secret. Soon after Taylor and Young's discovery, Bell Telephone Laboratories developed the cathode ray tube (CRT). The CRT, which became available in 1923, was used in early radar systems to display the transmitted signals or "raw data". The data was then interpreted by skilled operators.[184]

During the 1930s, NRL and the Bureau of Engineering conducted experiments on radar technology RCA also initiated basic research on radar techniques and apparatus. In 1932, microwave equipment developed by RCA was used in secret tests conducted in cooperation with the U.S. Army's Signal Corps to demonstrate that ships could be detected and located by means of microwaves.

The earliest form of radar was the "pulse type", which was developed during the 1930s, and consisted of a rotating antenna that scanned the horizon. The pulse type generated short bursts, or pulses, of energy that were transmitted along a line of sight path. This method of propagation meant there was an unobstructed path from the radar antenna to its target. The pulses were reflected by dense objects (i.e., mountains, buildings, ships, aircraft, and surfaced submarines) that were in the path of the transmitted radio wave. The reflected pulse then returned to the radar receiver as an echo The radar receiver retrieved the pulse and measured the time required for the pulse to travel from the transmitter back to the receiver. The larger and closer the object, the louder the echo.185

In 1935, the Naval Appropriations allotted $100,000 to NRL to conduct research. By the late 1930s, NRL had installed the first complete radar antenna, "Topsy", at one of its buildings in Anacostia. The radar system consisted of a "directable" antenna that rotated for a 360-degree coverage. By the late 1930s, both Bell Laboratories and RCA were working in cooperation with NRL on radar R&D.186

By the summer of 1940, radar had emerged from its developmental stage. Work on radar continued in secrecy under strict military security throughout World War II. This period was marked by intensive R&D efforts to develop new radar equipment for military use. In August 1940, General Electric established a radar production plant to assist in the war effort. By 1941, RCA, General Electric, Westinghouse Electric, and Bell Laboratories were deeply involved in the Navy's research efforts, as well as in initiating commercial production. Radars designed by Bell Laboratories, and produced by Western Electric, were used in ground, air, and ship-based systems. The Massachusetts Institute of Technology's (MIT's) "Rad Lab" also played a major role in the development of radar during World War II. Established in 1940 under contract with the Office of Scientific Research and Development (OSRD), the Rad Lab provided the Allied forces with radar equipment and explored the potential for microwave radar Scientists from all over the U.S. assembled at the Rad Lab to develop and test new radar equipment. In addition, the Navy established its own unit for radar design, procurement, installation, maintenance, and training. This radar unit continued to function as a separate entity until late 1942.187

During the five years of war, total production of communications equipment amounted to $10,659,000,000. This included $4,433,000,000 for radio; $3,719,000,000 for radar Throughout the war, radar was used successfully to detect and locate aircraft, ships, and other targets. As a result of this intensive effort, many advancements in radar technology were introduced. One important development was the "klystron", an ultra-high frequency microwave tube, which was used in radar and aircraft guidance. Other developments included the CRT, microwaves, television, and timing circuits. Advancements in radar technology also had many important civilian applications, particularly in navigation for ships and aircraft.188

Most radars developed during World War II operated in a shorter-wave frequency band (5,200-10,900 MHz) and the longer-wave microwave band (1,550-5,200 MHz). Later developments during the Cold War era broadened the frequency spectrum from 100 MHz to 60,000 MHz. Another important development of radar systems during this period was their ability to track in three dimensions, including range, direction, and altitude.189 Large, complex antenna arrays were displaced by simpler antennas, such as parabolic reflectors, as radars progressed to shorter wavelengths.190

During the 1950s and early 1960s, the radar market was greatly expanded as a result of the introduction of major air defense systems, such as Ballistic Missile Early Warning System (BMEWS) and SAGE. The NASA and DoD ranges also were being equipped with range instrumentation radars, and the National Airways System installed air traffic control radars. The 1960s, on the other hand, focused on the operation and maintenance of these systems, as well as continued R&D efforts. The 1970s were marked by an extensive R&D effort to develop a new generation of radar systems, including phased array and OTH radars.191

Associated Property Types

Over-the-Horizon (OTH) Radars

Radar generally covers the "microwave" region of the electronic spectrum meaning that they are limited in range to the radar horizon. Over-the-horizon (OTH) radars utilize the sky wave propagation method to detect targets from 600 to 2,500 miles range. OTH radars transmit low-frequency (LF) beams that follow the curvature of the earth and utilize the ionosphere as a reflector. OTH radars, as a result, are used in strategic defense and surveillance roles to detect incoming aircraft, missiles, and ships at sea. They also provide a significant measure of early warning in the event of a strategic nuclear attack. Depending on the particular system, the receiver may be located nearby or at a great distance from the transmitter.192

NRL developed their first OTH radar, "Music", in 1954 which was used to detect both atomic explosions and missile launchings. Between 1956 and 1958, work was undertaken to develop a high-power "Madre" radar. Madre stood for "magnetic drum radar equipment." By 1961, NRL had developed an operational system, which was used to detect low-velocity targets at ranges out to 1,000 miles. This system was installed at NRL's Chesapeake Bay radar research site. The radar consisted of a large, fixed antenna measuring 300 feet wide by 140 high and a smaller, steerable reflector antenna. The operations building contained the transmitter and the receiving, data-processing, and display equipment.193 At a speaking engagement in California in September 1968, President Lyndon B. Johnson proclaimed this development as a "major increase" in the United States capability to detect hostile missile launchings. "Over-the-horizon radar", he said, "makes it possible to spot enemy missiles from anywhere on earth in seconds after they leave the ground."194

A Relocatable-Over-the-Horizon Radar (ROTHR) system was developed by Raytheon Corporation during the 1980s for the U.S. Navy. A similar system, the continental over-the-horizon-backscatter (CONUS OTH-B), was developed by General Electric for the U.S. Air Force. ROTHR is a tactical, bi-static ionospheric backscatter system designed to provide wide area surveillance of both aircraft and ships. Although the system is described as "relocatable", this feature only applied to the transmitters, receivers, and the operational control center. The transmitting and receiving antennas, on the other hand, were designed as permanent fixtures. The ROTHR system consists of three distinct elements: a transmitter site; a receiver site; and an operations control center. The transmit and receive sites are separated by a distance of approximately 50 to 100 miles. The transmit site contains equipment to generate the high power waveforms of the ROTHR system, and to radiate this energy within the desired surveillance area. The receive site contains equipment for the reception and signal processing of energy backscattered from the surveillance area for both target detection and propagation. Both the transmit and receive sites are controlled remotely from the Operational Control Center (OCC).195

In 1985-1986, Raytheon Corporation installed the ROTHR system at NSGA Northwest. The system at Northwest operates as the receiver site; New Kent, Virginia, operates as the transmitter site. The control center provides instructions to the transmitter site for radar illumination. The receiver site receives the returned beams and converts them digitally in the signal processor; it also carries out the range and Doppler processing and extracts target detections. The detections are then passed to the operations center.196

The receiver site at Northwest contains a mile-long antenna array, the Quasi-Vertical Incident (QVI) antenna, the Cal antenna, a storage/receiver building (Building 305), and an operations building (Building 344). The antenna configuration consists of 372 pairs of antenna arrays aligned along a linear row extending approximately 8,574 feet (Figure 28). Each antenna array is formed by paired metal posts that measure approximately ten feet in height. The arrays are spaced roughly 14 feet apart and are mounted on concrete pads. The paired arrays are connected to each other by metal wiring conduits. A metal duct, which serves as the equipment shelter, extends the entire length of the antenna array; the duct connects the antenna to the operations building (Building 344). The ROTHR system functioned in tandem with the QVI antenna, which was designed to model the ionosphere.

AN/FPS-117 Radar

Advances in solid state digital technology made in recent years have led to significant advances in radar technology, such as increased signal and data processing. The availability of low cost, small size digital processing technology has resulted in substantial improvements in the types of systems produced. For example, digital circuitry resulted in the development of an automatic detection and tracking (ADT) system, which is capable of accurately detecting and tracking several hundred aircraft simultaneously. Before this advanced technology, an operator was capable of tracking a handful of aircraft.197

The Model AN/FPS-117 radar system, which was designed and manufactured by General Electric Company, incorporates the latest solid state electronics. The system provides data on distance, direction, and altitude and has a range of up to 250 nautical miles (nm). The radar relies on sophisticated computer equipment to process data, control transmission power and radar beams, adjust the equipment to prevailing conditions (e.g., weather, landscape), supply information on conditions, and calibrate the equipment. The AN/FPS-117 radar system is used widely outside the United States, at sites located in Germany, Saudi Arabia, and South Korea.198

Four remote radar sites that utilize the AN/FPS-117 radar system were constructed in Iceland during the late-1980s. These radar sites, which are operated by the Radar Agency, are situated in remote locations along the northeast (Gunnolsvikurfjall), northwest (Bolafjall), southeast (Stokknes), and southwest (Midnessheidi) coasts. Each radar station employs a similar overall layout consisting of a main operations building, a radome, and two support structures (Figure 29). The main operations building typically measures 11,840 square feet and contains accommodation for employees, equipment storage, and maintenance and repair facilities. The radome, which houses the antenna system, is raised on a steel-frame platform and rises 76 feet above ground level. The radomes are constructed of riveted steel panels. An emergency power station is located at each station.199

Phased Array Radars

Recent technological developments, particularly the advent of electronically controlled phase shifters, has directed attention to phased array radar. Phased array radars do not utilize conventional, mechanically scanned antennas. Instead, they consist of hundreds or thousands of small emitters which are controlled, or "phased", by computer to generate electronically scanned beams. The main advantage of a phased array system is that it can simultaneously track several targets, steer several missiles, and search for other targets or aircraft. This capability is called TRACK-WHILE-SCAN. The earliest phased array radars were very large systems that were designed to detect an incoming nuclear attack. These large phased array systems utilized lower frequency ranges to increase power and long-range detection.200

During the 1960s, Bendix developed the first phased array project in the United States, the Model AN/FPS-85 Long Range Phased Array Radar. The system originally was designed as the main U.S.-based active sensor of the SPACETRACK system. The FPS-85 receives its SPACETRACK directions from the NORAD Space Defense Center. The large cost and high level of complexity of electronically steered phased array antennas, however, have limited their application to date.201

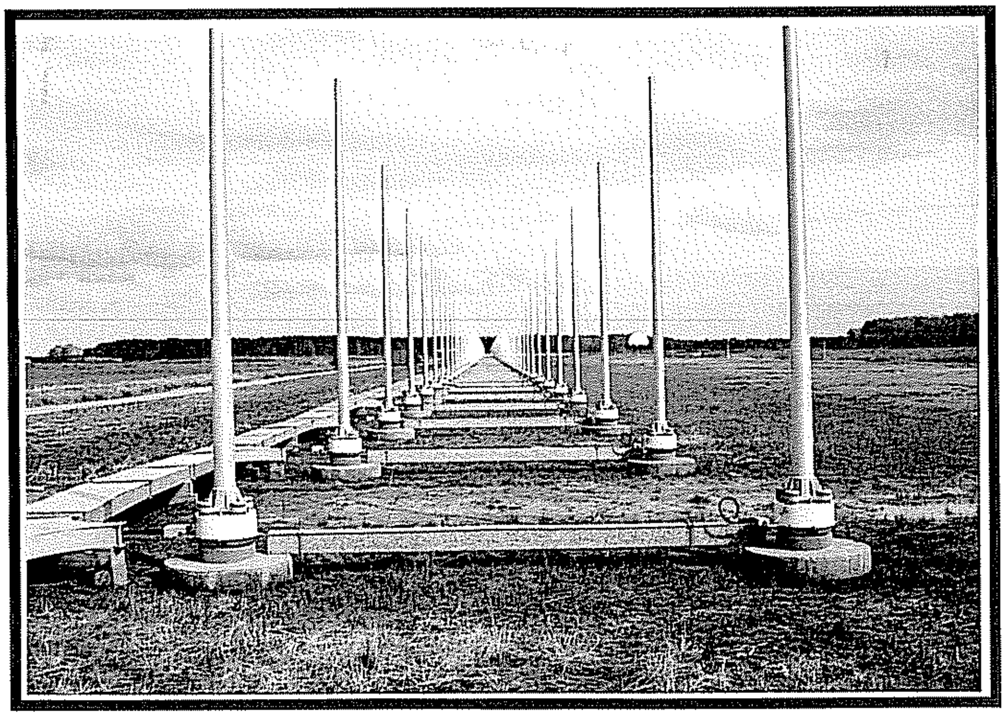


Figure 28. View of Relocatable-Over-the-Horizon (ROTHR) antenna at NSGA Northwest, Virginia. The antenna configuration consists of 372 pairs of antenna arrays aligned along a linear row extending approximately 8,574 feet.

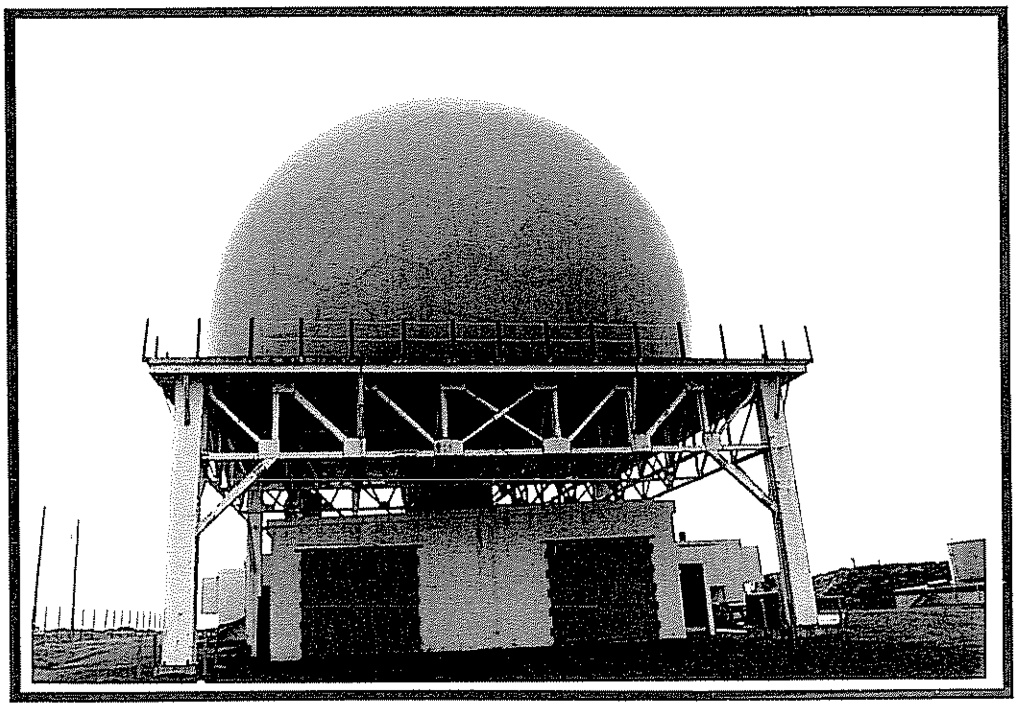


Figure 29. View of remote radar facility at H-4A Site constructed during the late 1980s for the Naval Air Station (NAS) Keflavik, Iceland. The radar site is equipped with the AN/FPS-117 radar.

DIRECTION FINDERS (D/F)

Introduction

A direction finder (D/F) is a special type of receiver used to determine the bearing of a transmitting station. Although the Navy relies more on radar than direction finding for electronic navigational aid, D/F is still important in search and rescue operations and for fixing the location of enemy radio and radar stations. D/F stations operate by transmitting data from the outstations back and forth with the control station where plotting and analysis are completed.202 Naval D/F stations typically are separated from each other by hundreds of miles to compensate for the long distances involved in naval communication. Four radio D/F stations typically are used to accurately locate or "fix" a target. A single D/F station can provide only azimuth, or line bearing, from the station to the target along a straight line. (A bearing provides the direction to the target but not the distance.) Two D/F stations sighting on the same target can provide intersecting line bearings, which provide both direction and approximate distance from the point of intersection back to the baseline. Three, and preferably four, D/F stations can provide three or more intersecting bearings called a "fix", which form a triangle of intersecting lines.203

Evolution of Direction Finder (D/F) Systems

Developments in radio direction finding (D/F) antennas attracted interest during the early-twentieth century. Essentially, D/F antennas were designed to locate signals transmitted from fixed or mobile stations. Both Bellini-Tosi and Telefunken had received patents for devices. The Bellini-Tosi apparatus consisted of a large, umbrella-type antenna system of radial wires measuring about 100 feet in length. The Telefunken equipment more closely resembled an early version of a radiobeacon or homer. It consisted of a mast approximately 100 feet high with radiating antennas. In 1912, Marconi acquired the patents and began installing the antennas in commercial ships. These first radio antennas allowed ships at sea to get standardized times and locations from shore stations.204

In 1916, the Navy Department adapted a direction finder, developed by Dr. Frederick A. Kolster of the Bureau of Standards, for shipboard installation. The radio shop of the Philadelphia Navy Yard was charged with the task of modifying Kolster's direction finder to meet shipboard requirements. By the end of 1916, twenty of these direction finders were fitted on battleships and cruisers.

During the early 1920s, NRL was involved in developing the Model XM direction finder. A number of these systems were produced and installed in the Navy's coastal D/F chain to upgrade its performance. The Model XM was followed by the procurement of a series of direction finders for the Navy's shore stations, including the Models DK (1930), DM (1931), DP (1934-1942), DAF (1942), DAH (1942-1944), and DAP (1942).205

In 1936, NRL was successful in developing a high frequency D/F. D/F's of this type were produced in considerable quantities and were installed along the Atlantic and Pacific coasts and in Oahu, Hawaii. This system played an important role in the antisubmarine campaign throughout World War II.206 Following World War II, NRL continued to make advancements in D/F systems. Many of these systems are still in use by the Navy.

Associated Property Types

Model AN/GRD-6 Improved HFDF Antenna

In 1958, NRL developed the Model AN/GRD-6 Improved HFDF Antenna. This early direction finder system consisted of a circular array of metal poles.207 The Model AN/GRD-6 was supplanted by the AN/FRD-10 Circularly Disposed Antenna Array (CDAA).

Model AN/FRD-10 Circularly Disposed Antenna Array (CDAA)

NRL was involved in a number of experiments during the early 1950s to increase bearing accuracy using a wide aperture high frequency D/F. Based on the results of these experiments, NRL developed the first U.S. wide-aperture, circularly disposed radio direction finder in 1957, the Model AN/FRD-10 circularly disposed antenna array (CDAA). This new system, known as the "Wullenweber", provided greatly improved direction finding bearing accuracy. This system was arranged in a circular configuration and consisted of a series of broadband sleeve antennas arranged in front of a reflector screen. An operations building located at the center of the array contained the electronic equipment for directing the beams. This system was installed in Hybla Valley, Virginia, where it was used to determine the orbit of the Russian satellite, Sputnik I, on October 4, 1957.208

The AN/FRD-10 system has been installed at NAVSECGRU activities and at Naval communications stations throughout the world. These systems, which operate in the high frequency spectrum, are used as an all-purpose communications receiving antenna and for its D/F capability. The network they form is used to intercept and correlate information from a variety of signal sources. Representative examples of the Wullenweber system were visited at NSGA Northwest, Virginia; NSGA Sabana Seca, Puerto Rico; and NSGA Winter Harbor, Maine. All of these systems were installed during the early 1960s and are characterized by slight variations in their overall design. Each system is composed of two circular, concentric arrays (Figures 30 and 31). Each array receives signals independently of the other. The inner array, which is used for low-band radio signal reception (2-9 MHz), consists of 40 folded monopole antenna elements with a radius of 393.5 feet, and a 90-foot high circular reflecting screen. Each low-band antenna consists of an aluminum mast supported by guy wires and anchored to a concrete foundation. The mast functions as the principal RF element in the reception of radio signals. The low-band reflector screen, which is located 27.5 feet behind the low-band antenna, consists of 640 vertical screen wires and 80 wood support poles spaced equidistantly from each other. A horizontal "boom board" extends along the top of the poles and is used to support the vertical screen wires.209

The outer array, which is used for high-band radio reception (9-32 MHz), consists of 120 sleeve monopole antenna elements, and a 24-foot high reflecting screen. The typical radius of the high-band antenna is 436.75 feet (the radius at Adak, Alaska; Skaggs Island, California; Edzell, Scotland; and Winter Harbor, Maine measures 431.75 feet). The high-band reflector screen, which is similar in configuration to the low-band reflector screen, consists of 1,920 vertical screen wires and 120 wood support poles. Underground coaxial cables are used to conduct the RF signals received by each antenna element. These signals are routed to the operations building located at the center of antenna array. The operations building contains a rotatable goniometer, which provides the direction finding capabilities. The system operates by rotating the goniometer to pick up the maximum signal strength, which indicates the direction of the signal. In addition to these arrays, the CDAA system includes an extensive reflecting ground plane. The ground plane functions by reflecting the vertically polarized incident waves from both the low-band and high-band arrays. Radials, spaced one degree apart, extend outward from the ground mat approximately 150 feet.210

The CDAA system at Winter Harbor is characterized by a slightly different configuration from those at Northwest and Sabana Seca (Figure 32). Instead of wood support poles at the low-band reflector screen, the CDAA system at Winter Harbor contains forty, three-legged steel

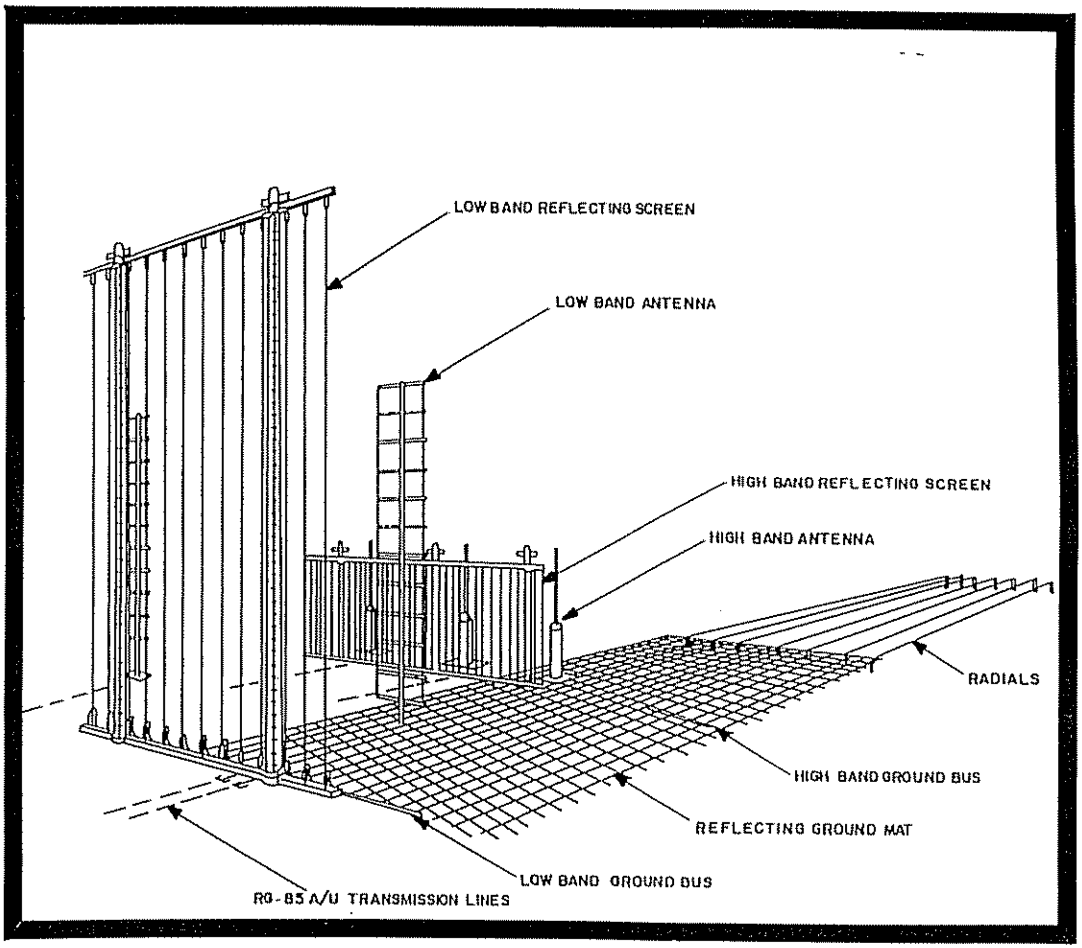


Figure 30. Diagram showing the major components of a typical Circularly Disposed Antenna Array (CDAA) system, including ground radials, a reflecting ground mat, low band and high band reflection screens and their associated antennas, and transmission lines ("CDAA Electronic Maintenance (AN/FRD-10) Technical Manual", 1-4).

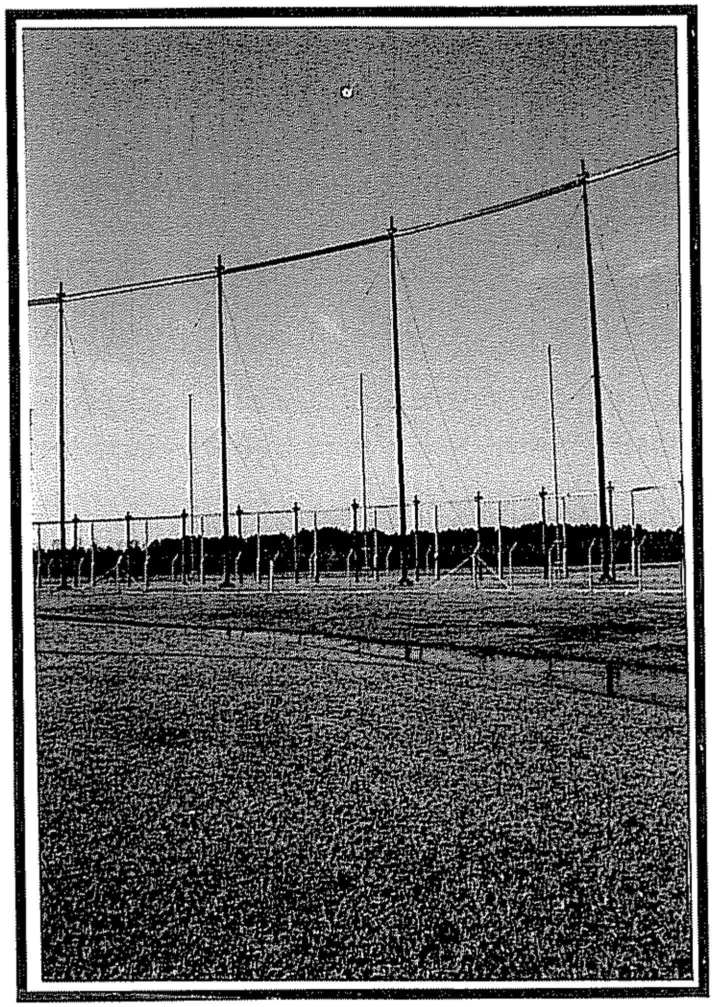


Figure 31. Detail of CDAA system. The antenna array consists of four concentric rings, including a high frequency (HF) and low frequency (LF) antenna and associated reflector screens

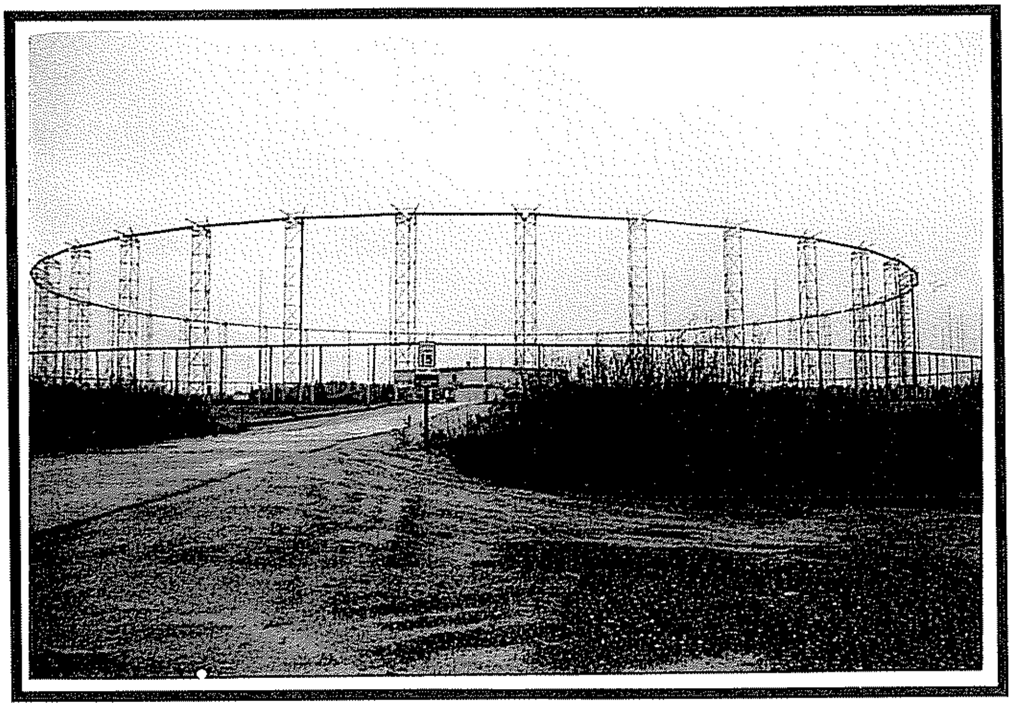


Figure 32. The CDAA system at Winter Harbor, Maine, employs a slightly different configuration from the CDAA system at NSGA Northwest. Instead of wood poles, the low-band reflector screen contains forty, three-legged steel towers.

towers. Wood poles comprise the HF array. Only two other sites, Guam and Okinawa, contain similar CDAA facilities. Each of these facilities were intended as experimental sites, with each tower utilizing a slightly different design.211

Model AN/FLR-9 CDAA

The Model AN/FLR-9 CDAA system also was developed during the 1950s. This system, referred to as an "Elephant Cage", is defined by three circular arrays, as opposed to the two arrays that typify the AN/FRD-10 system. An operations building is located in the center of the triple array, which contains the electronic equipment for forming the directional beams for monitoring and direction-finding. The entire system measures about 900 feet in diameter. An underground tunnel connects the antenna array to the operations building.212

TROPOSPHERIC SCATTER SYSTEMS

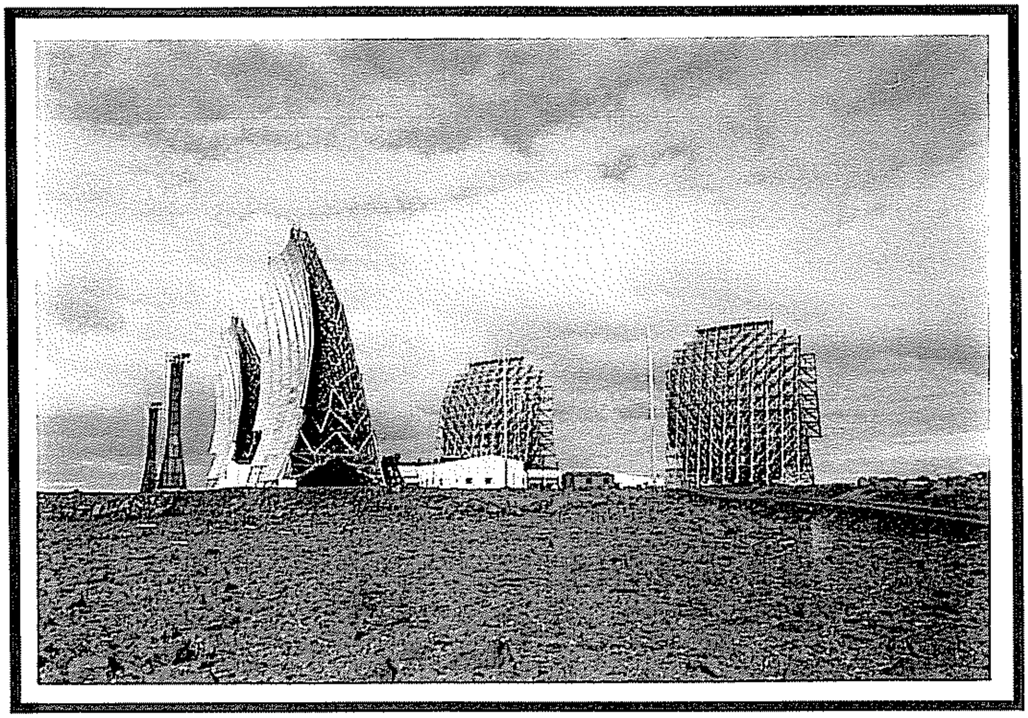
Introduction

Tropospheric scatter systems rely on the turbulence in the atmospheric layer between the troposphere and the stratosphere to bounce signals back to earth. The signal strikes the tropospheric layer, which lies only a few kilometers above the ground, at a shallow angle that can be transmitted up to 800 kilometers (500 miles). A major disadvantage of this method is the high rate of power loss, thus requiring the use of large and powerful radio transmitters.213

Evolution of Tropospheric Scatter Systems

Between 1954 and 1969, NRL conducted the first investigation of surface-to-surface tropospheric scatter propagation to test its feasibility for Naval communications. In July 1955, NRL demonstrated successfully ship-to-shore, two-way, voice communication with the tropospheric mode of propagation over a distance of up to 250 miles. NRL concluded from these experiments that, with sufficient transmitter power and high-gain antennas, tropospheric scatter communications were possible.214

Naval Air Station (NAS) Keflavik, Iceland, provides an example of a tropospheric scatter system constructed during the 1960s. Known as the Dye-5 Site, or "Elephant Ears", the system was dominated by four, large parabolic antenna dishes facing each other (Figure 33). The Dye-5 site contained a very powerful transmitter (50 kw) capable of transmitting signals to a similar site in Greenland. The transmitter system continued to "hop", through a series of transmitter sites, to the United States and continued to Turkey. This system represented state-of-the-art technology for its time, and illustrated the evolution of communications systems from the ionospheric to tropospheric range. The Dye-5 Site included an operations center (Building 893) and was supported by a receiver and transmitter site, and two other remote sites (Sites H-1 and H-3). The DYE-5 tropospheric scatter system has become obsolete with the introduction of satellite communications. The Keflavik site, along with the other tropospheric scatter sites, are no longer operational and are scheduled for removal.



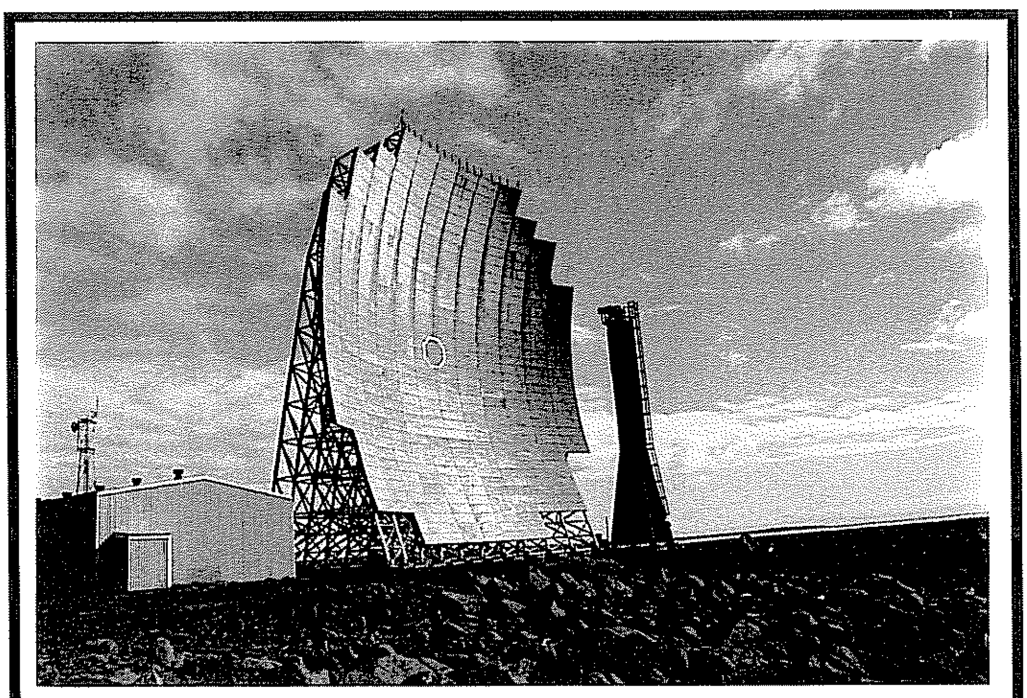


Figure 33. Above: Overall view of the Dye-5 Site at the Naval Air Station (NAS) Keflavik, Iceland. Below: Close-up view of antenna array at Dye-5 Site.

ELF/VLF/LF SYSTEMS

Introduction

Radio frequencies below the broadcast band are designated very low frequency (VLF), low frequency (LF), and medium frequency (MF). These lower frequency ranges are used primarily by the Navy for communicating with ships and submarines. Extremely low frequency (ELF) radio signals are well-suited for communicating with submerged submarines since they have the ability to penetrate the ocean to a depth of several hundred feet without signal loss. ELF operates as a one-way communication system from the operating authority to submarines at sea. Due to the large size of the required antenna system, it is not practical for installation onboard submarines. Another drawback of ELF communications is their very slow transmission speed. In addition, transmitters for the system are very large, consisting of an antenna system miles in length. The U.S. has one ELF station.215

VLF signals (3-30 KHz), unlike ELF radio signals, penetrate only a few meters through the water. However, VLF bands can transmit data at a faster rate using a shorter transmission antenna than ELF systems. VLF systems are used primarily for one-way transmissions to submarines and ships. VLF transmissions also provide a highly reliable path for communicating with northern latitudes, such as those of the North Atlantic and Arctic Ocean. The more traditional HF circuits do not perform well in these areas due to local atmospheric conditions. At present, the majority of the Navy's VLF transmitters are used for fleet communications or navigation. Like ELF, VLF transmissions operate as a one-way communication system. VLF currently is used for communicating to large numbers of satellites and as an emergency back up in the event of a nuclear attack.216

LF signals (30-300 KHz) have a relatively short transmission range of between 560 and 1,050 miles. Antenna transmitter systems for LF communications consist of smaller structures, typically 325 to 655 feet. Radio signals of LF systems can only penetrate a few centimeters below water and the signal reception is easily disrupted by atmospheric noise. As a result, LF communications are best-suited for two-way communication, such as that between bombers or submarines and their bases during nuclear attack.217

Evolution of ELF, VLF, and LF Systems

The Navy expressed early interest in very low frequencies for use in long-distance communication from shore to ships at sea. Radio waves transmitted at LF or VLF can travel past the curvature of the earth, bounce off the atmosphere, and return to earth, where they can be picked up. Very high power could be radiated from the huge antennas used at these frequencies, making world-wide coverage possible. By the end of World War I, the Navy had established a chain of high-power arc stations for this purpose.218 The Naval Radio Transmitter Facility (NRTF) Annapolis was established during this period and operated as a low-frequency (LF) communications link between the U.S. and Europe during World War I. The Annapolis station represented one of the most powerful transmitter station in the United States.219

During the late-1940s, the Navy's communications planners recognized the need for a very high power, VLF radio transmitter to broadcast to the North Atlantic and Arctic. In 1953, Radio Jim Creek was established in Snohomish County, Washington, as the world's most powerful radio transmitter. The VLF station produced a power output in excess of one million watts, and was capable of providing reliable, high power VLF broadcasts to Navy fleets far at sea. The Jim Creek facility consisted of twelve, 200-foot steel towers constructed along 3,000 feet of mountain ridges to support the giant antenna system. In 1956, Congress appropriated funds to purchase a 2,850-acre peninsula in Cutler, Maine, to establish another VLF transmitter station. Construction of the Naval Communications Unit Cutler was initiated in January 1958 and largely completed by January 1961. The site contained two antenna arrays composed of thirteen 800-foot to 900-foot towers and 75 miles of phosphorous bronze wire.220 The Navy established additional VLF sites at Summit, Panama Canal Zone; Lualualei, Hawaii; Haiku, Hawaii; and Northwest Cape, Australia.221

During the 1950s, NRL conducted world-wide radio wave propagation studies to assess the capability of the Navy's chain of high power VLF stations to communicate with its Polaris submarines.222 By the 1960s many of the Navy's earlier, now obsolete, VLF transmitter systems were upgraded to accommodate newer, state-of-the-art systems.

Additional LF transmitter sites were established during the 1960s, including the Naval Low Frequency Transmitter Facility (NLFTF) Aguada, Puerto Rico (Figure 34). NLFTF Aguada was established in 1968 along the northwest coast of Puerto Rico to serve as a nuclear submarine broadcast site. A 1,200-foot transmitting tower is used to support this mission. The site enables submarines to communicate with other submarines and shore facilities once they have surfaced and activated their HF equipment.223 Only six similar LF sites were operated by the U.S. and include Cutler, Maine; Australia; Jim Creek; Lulu Lake; Japan (closed); and Annapolis (closed).224

Associated Property Types

Model AN/FRT-72 LF "Marconi Triatic" Array

An example of a World War II era LF antenna system is the "Marconi Triatic" array (Model AN/FRT-72). A triatic antenna is designed to transmit from a particular location. This LF transmitter was installed at NRTF Annapolis in 1942 to provide a reliable radio link between Washington, DC, and Europe for the Navy Department during World War II. The antenna system consists of three, 800-foot steel towers and its associated "Marconi Triatic" array. Two sets of wires extend from the top of each tower; each wire then spreads into four radiating tracks to form a wide band system. Each set of wires connects to the adjacent tower forming a "triatic array". A feed line extends from the midsection of one of the wide bands to the power source, or helix house. Two of the towers operate at one frequency, and the third tower operates at another frequency.

Model AN/FRT-87 VLF "Modified Goliath" Antenna

The Model AN/FRT-87 VLF transmitter represents one of these newer generation of communications systems. This system, which was installed at NRTF Annapolis in 1969, is capable of operating four channels synchronously (Figure 35). The system was designed by Continental Electronics and consists of a 1,200-foot tower and nine 600-foot support, or guide, towers. The antenna array extends from the top of the 1,200-foot tower and radiates outward to the guide towers. The main feed line extends from the helix house to three different heights along the 1,200-foot tower. The entire antenna array occupies 20 acres. Messages transmitted via the VLF system run through 4 1/2-inch thick copper wire. The Model AN/FRT-87 VLF transmitter is capable of communicating with submerged submarines 50 to 60 feet below the surface.225

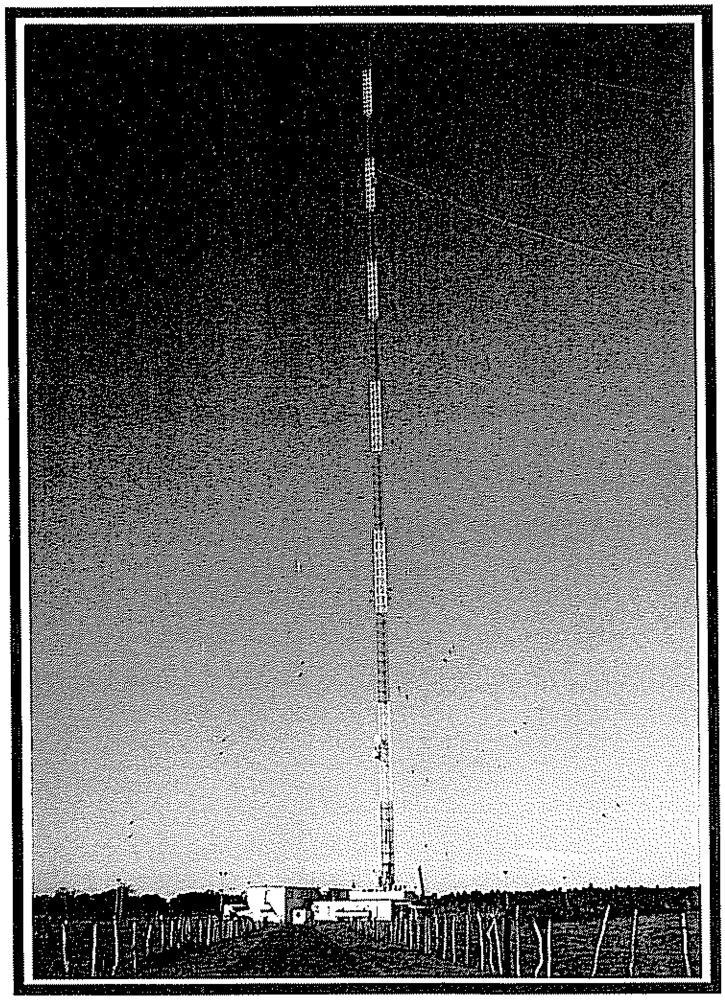


Figure 34. Overall view of the Naval Low Frequency Transmitter Facility (NLFTF) Aguada, Puerto Rico, showing the 1,200-foot tower in the background. NLFTF Aguada was established in 1968 to serve as a nuclear submarine broadcast site.

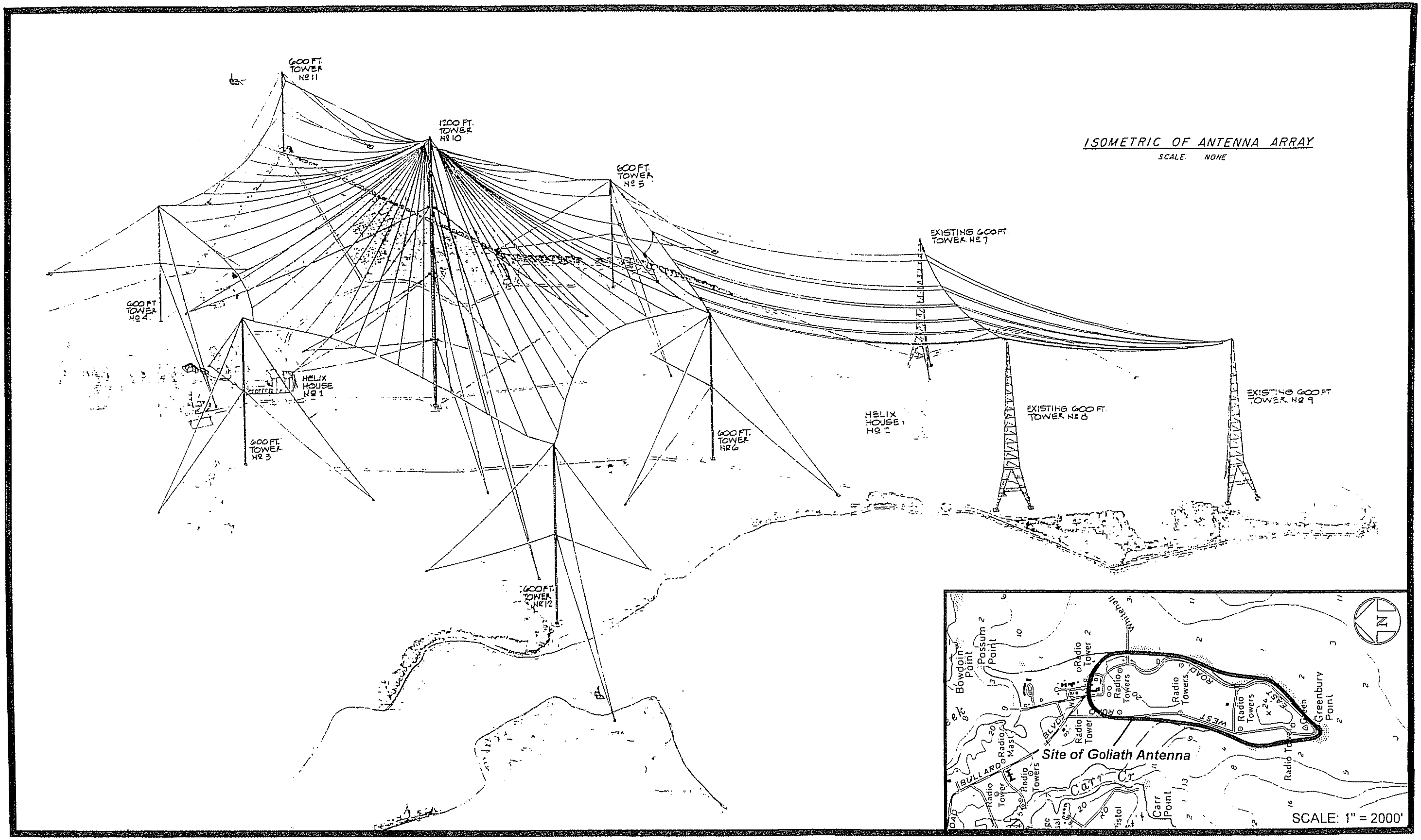


Figure 35. Isometric of VLF "Modified Goliath" antenna array installed at NRTF Annapolis in 1969 (Courtesy of NRTF Annapolis) and portion of USGS Annapolis Quadrangle map showing location

HIGH FREQUENCY (HF) SYSTEMS

Introduction

High frequency (HF) band, or short-wave, is of major importance to the Navy and carries the bulk of the service's long-distance communications traffic. HF signals (3-30 MHz) require minimal amounts of transmitting energy to send messages great distances. The main advantage of HF antennas is their relatively small size in comparison to the size required for lower frequencies. For example, HF signals can be transmitted from a small, low-power antenna to receivers all over the world. Long-range HF bands also utilize the ionospheric layer of the atmosphere. A major disadvantage is that the signals are vulnerable to disruptions such as nuclear explosions, humidity, and seasonal effects. HF transmissions also are easily intercepted and jammed. The upper portion of the HF band is dedicated to radar astronomy, such as retrieving echoes from the sun's ionized atmosphere. Satellite communications, which utilize the SHF band, are slowly replacing the military's use of the HF spectrum.[226]

Naval communications within the HF band can be grouped into four general categories: (1) point-to-point; (2) ship-to-shore; (3) ground-to-air; and (4) fleet broadcast. Point-to-point systems communicate over long distance "links" between fixed terminals. A link is a transmitter-receiver system connecting two locations. Ship-to-shore systems communicate between a ship at sea and a shore communication station. Although the types of antenna systems installed on board ships are limited, the shore stations are able to employ omni-directional antennas or arrays capable of covering large areas of the earth's surface. Omni-directional antennas radiate energy waves in all directions simultaneously and may include rotatable, high-gain, or rhombic antennas. Ground-to-air systems is similar to ship-to-shore. Higher powered transmitters, lower noise receivers, and highly efficient antennas are employed at shore stations to accommodate the increased speed of an aircraft, as opposed to a ship. Fleet broadcast systems involves a broadcast area coverage from shore-based transmitters to ships at sea.[227]

Evolution of HF Systems

The Navy began using HF for radio communications during World War I. Much of NRL's initial R&D work explored the HF radio frequency spectrum. During the 1920s, resources were directed towards developing higher-powered tube transmitters and improving high-powered arcs. NRL experimented with radio propagation, quartz-crystal frequency control, and power generation. The laboratory also was involved in studying the characteristics of the ionosphere using HF pulses reflected from its conducting layers. As a result of this early research, means for generating short, high-power HF pulses were devised. These developments led to the adoption and extensive utilization of HF systems by the Navy.[228]

HF transmitters and receivers developed by NRL were installed on the Navy's ships and at shore stations. During October 1924, the Navy's dirigible, U.S.S. Shenandoah, made its transcontinental flight from Lakehurst, New Jersey, to the west coast and back. The dirigible was successful in communicating with many stations throughout the trip using the new HF equipment. As a result of this success, the Bureau of Engineering included deploying HF equipment in the Navy's Radio Modernization Plan of 1926. Interest in HF communications grew rapidly and many demands were placed on NRL by both the Navy and outside interests.[229]

During the 1930s and 1940s, NRL focused on developing HF transmitters with higher frequency stability, increased efficiency, greater reliability, and reduced size. These advances were incorporated into a series of HF transmitters procured by the Navy, including 15 shore-based models and 15 shipboard models.[230] By the 1940s, experimentation with the higher frequencies was underway at both commercial and military laboratories. Emphasis was placed on developing an improved vacuum tube capable of providing power at higher frequencies and on developing a means of transferring high-frequency energy from the transmitter to the antenna.231

Work undertaken during World War II resulted in significant advances in HF communications. The rapid expansion of the HF spectrum is reflected by the large numbers of HF systems manufactured and installed at Navy installations throughout the Cold War period. During the 1970s, the requirement for HF operations was reduced significantly with the introduction of satellite communications. Many of the Navy's HF communications systems were removed as a result. HF communications systems, however, continue to play an important role in the Navy's communications program.

Associated Property Types

Conical Monopole Antenna

In 1957, NRL developed the conical monopole HF antenna to meet the requirement for a low height, high-frequency (HF) antenna. An important design consideration was minimizing obstruction to landing aircraft at naval air stations. The conical monopole is an omni-directional antenna that provides a 3-to-1 frequency coverage. A major advantage of this system was a grounded base power feed, which did not require a separate HF transformer like most other systems developed by this date. Hundreds were installed at both Air Force and Navy air stations.232

The conical monopole antenna consists of radiating elements attached to the top of a central conducting support pole. The support pole is formed by three vertical posts connected by cross members. The radiating elements extend outward and downward to a point just below the pole's midpoint. The elements then extend downward and inward to a connecting ring at the base of the pole. Connecting cross-members extend from the midpoint of the pole outward to the vertical radiating members; these members form an "impedance transformer". Diagonal support wires are attached to the midsection of the antenna array and extend to the ground; ceramic insulators are installed on these support wires. The antenna is fed at a point between the ring and the pole.233

The Model CM-2002 conical monopole manufactured by Hy-Gain Electronics Corporation is similar in configuration to the NRL-designed antenna (Figure 36). The Model CM-2002 is an omni-directional, HF communications antenna that operates over a frequency range of 2.5 to 10 megacycles. The system can be used as both a high-power transmitting or receiving antenna. Due to its low angle radiation patterns, the system can be used for both sky wave medium and long range operations, as well as ground wave short range communications. The antenna consists of a central aluminum tower approximately 63 feet tall. The tower is supported by guy wires located at two points along the tower.234

Rhombic Antenna

Another common type of HF communications system employed by the Navy was the rhombic antenna. This system consisted of a wire suspended several feet from the ground from four posts, which formed a diamond configuration. Each side is approximately ten feet long. One end of the wire is attached to a coaxial cable that runs underground to a centrally located operations building.235

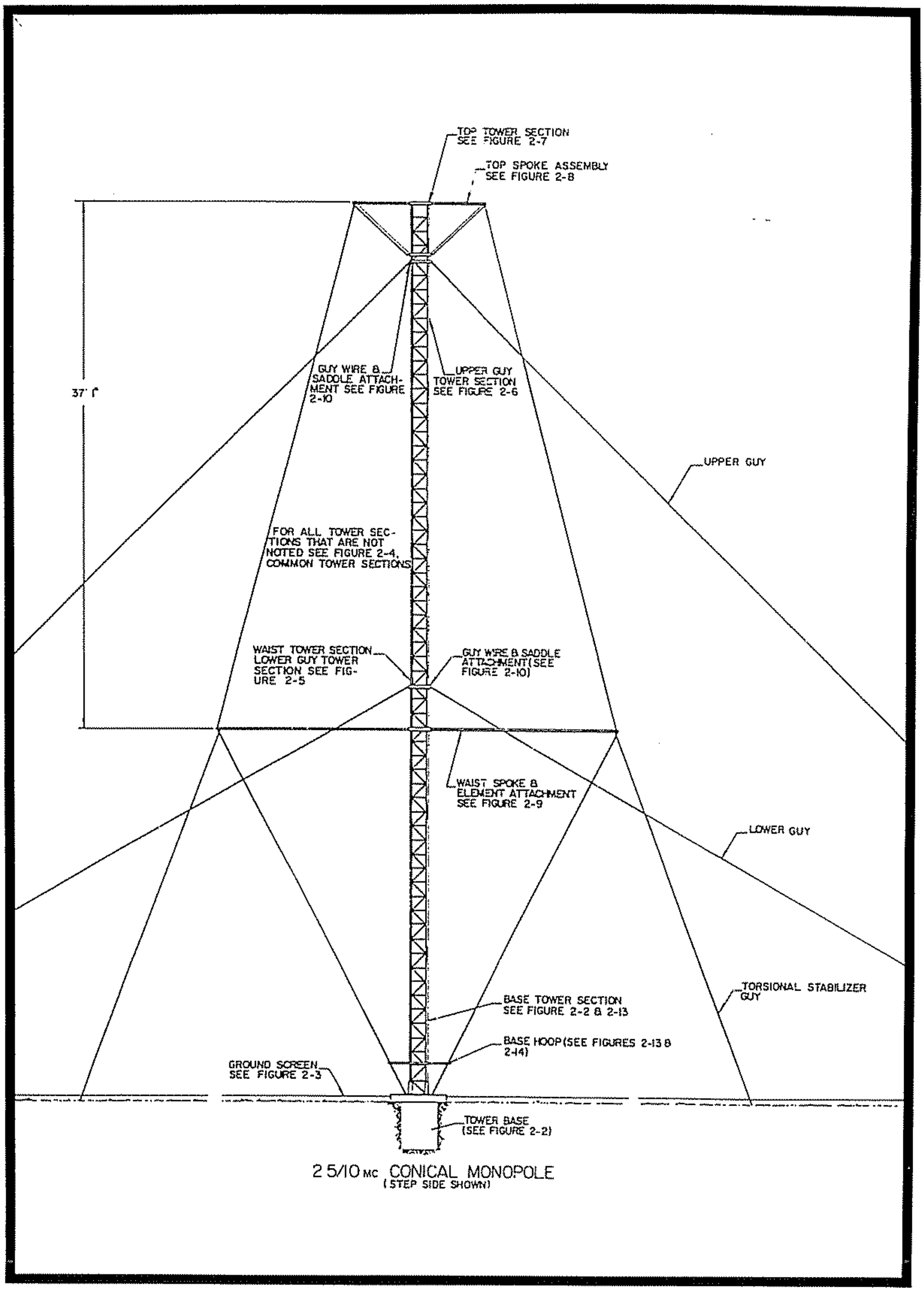


Figure 36 Diagram of Hy-Gain Model CM-2002 conical monopole antenna. The configuration is similar to NRL-designed conical monopole antenna (Taken from Hy-Gain Electronics Corporation, Technical Manual, "Model CM-2002 Conical Monopole Antenna")

Log Periodic Antenna

Log periodic antennas were developed during the 1960s. Figure 37 provides an illustration of one type of log periodic antenna. This version is formed by a central steel-frame tower with four radiating arrays.

The Model 530 and Model 532, both of which are manufactured by Technology Communications International (TCI), represent two other versions of log periodic antennas (Figure 38). The Model 530 is designed specifically to support reliable short range communications, and transmits its radio energy straight overhead using the sky wave propagation method. This antenna system is used for shore-to-ship and ground-to-air communications. Previously, ships had to transmit messages to distant stations. Due to the high take-off angle (HTOA) of this system, ships could now communicate with nearby stations. The TCI Model 532 is designed specifically to serve as a medium range communications system, with a range of 230 to 1,600 miles.236

The Model LPH-24C log periodic antenna was installed at NSGA Northwest, Virginia, and Naval Radio Receiver Facility, Salinas, Puerto Rico (Figure 39). The Model LPH-24C is characterized by its "fish-shaped" configuration. The antenna consists of an aluminum tower supported by four guy wires at the top of the structure. The antenna array is attached to the top of the metal tower and functions as a radiating, or rotatable, arm. The array contains a series of dipole elements tapered in length. A large metal "fin" is secured to one end of the array.

NRTF Isabela contains several examples of the Model LPH-89 rotatable log periodic (RLP) antenna. Figure 39 provides an illustration of this antenna system, which consists of a T-shaped configuration formed by a central tower supporting three steel-frame arms. Guy wires extend from the top and midsection of the central tower. Radiating wires extend from the T-shaped horizontal members to form a web configuration.

Inverted Cone Antenna

Inverted cone antennas represent another common type of HF system designed during the Cold War period. The Model 505-102 inverted cone antenna was developed during the late 1960s-1970s and is characterized by its inverted cone-like structure. The system consists of six vertical wood posts arranged in a circular configuration. The antenna array is attached to a horizontal guide wire that extends along the top of the posts and is formed by radiating diagonal elements that extend downward and inward to the midpoint of the circular array. A newer version, the Model AS-2212/FRC, AS-2213/FRC, and AS-2214/FRC inverted cone antenna, is illustrated in Figure 40. This system is manufactured by Granger Associates, Palo Alto, California, and is similar in configuration to the Model 505-102 inverted cone antenna. The antenna array is made up of 30, 600-foot radiating elements. This particular antenna system is of the vertically polarized, broadband, omni-directional type and is used for medium to long range communications with ships, aircraft, and other ground installations. This system is designed to transmit and receive signals in the 2 to 32 MHz frequency range.237

Omni Transmitter Antenna

Omni transmitter antennas also were used by the Navy as part of their HF communications systems. The Model 530-3 represents a common type of omni transmitter antenna used by the Navy for short range communications (Figure 41). The system, which is manufactured by TCI, can operate in the transmit or receive mode.238 The antenna consists of a central, vertical metal post that is 133 feet high. The central frame is formed by three separate posts arranged in a triangular layout and connected by diagonal cross members. A conductor wire is located within the vertical metal pole. The antenna array consists of a series of vertical wires and diagonal wires that extend from the top of the antenna structure. The diagonal arrays extend to four separate points to form a cross-shaped configuration. The outermost, diagonal radiating elements extend to the ground and are attached to a concrete pad. The other diagonal radiating elements extend downward and are attached to a horizontal guide wire near the base; support wires with insulators extend from the horizontal guide wire and are secured to the ground.

Horizontal Omnidirectional Broadband Antenna (HOBA) Antenna

The Model 540-2 Horizontal Omnidirectional Broadband Antenna (HOBA) antenna provides a more recent example of a HF communications systems (Figure 42). The system was developed by TCI during the 1990s as a horizontally polarized, omni-azimuthal HF antenna. This "state-of-the-art" antenna system is capable of operating two channels at the same time. The HOBA antenna consists of four, 99-foot galvanized steel towers, which support two radiating arrays. The radiating arrays, or curtains, are fabricated from "Alumoweld" wire. Diagonal antenna elements, attached at the top of each post, extend inward and downward to a central point. Horizontal members connect the diagonal members, forming an inverted pyramid configuration. A series of guy, or support, wires extend from three points along each metal post and extend to the ground.239

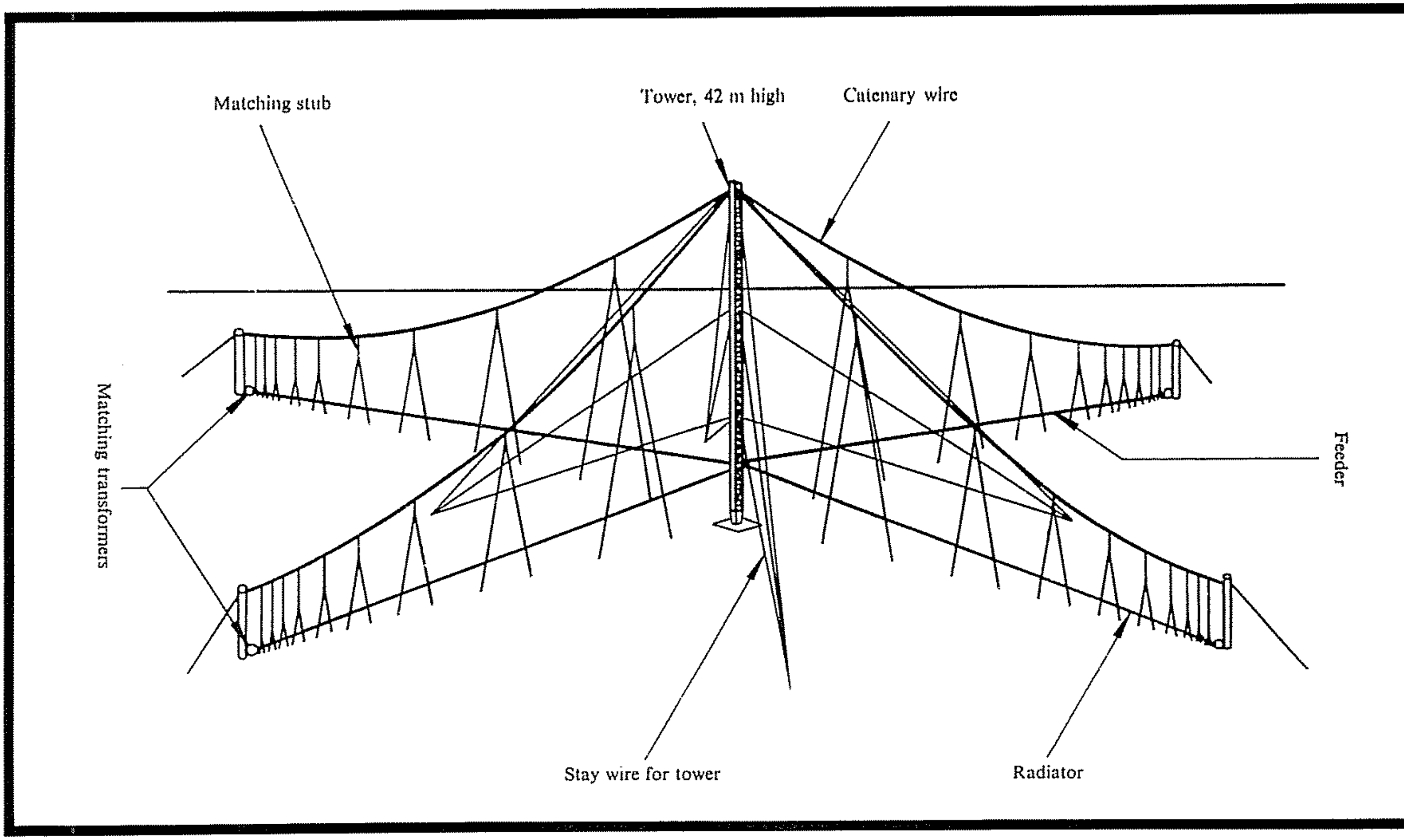


Figure 37. Log periodic HF antenna (Taken from *Handbook on High Frequency Directional Antennae*, 47).

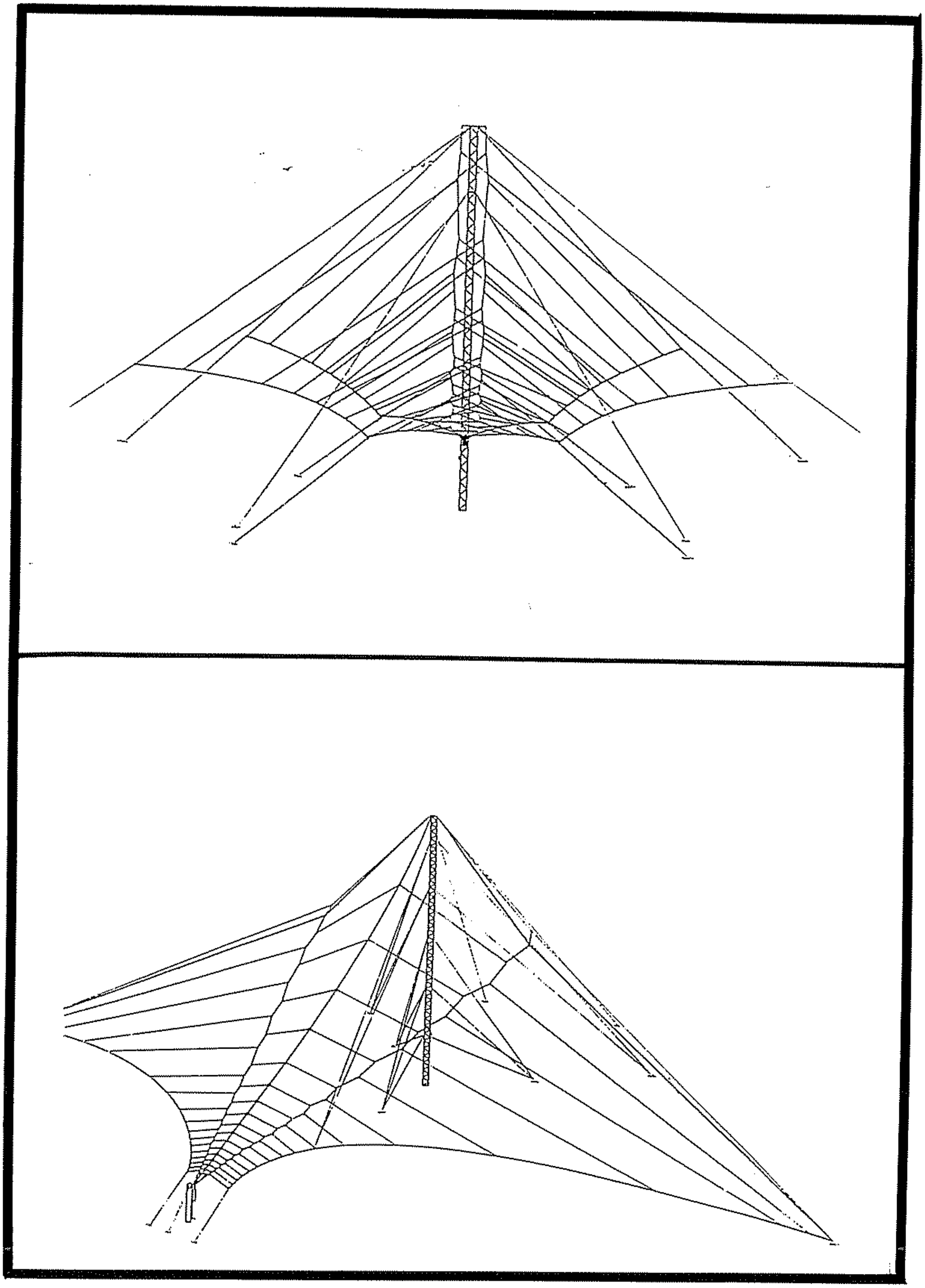


Figure 38. Above: Diagram of TCI Model 530 Log Periodic Antenna. Below: Diagram of TCI Model 532 Improved Medium Range Log Periodic Antenna (Taken from TCI Technical Manuals, "Model 530 Log Periodic Antenna" and "TCI Model 532 Improved Medium Range Log Periodic Antenna").

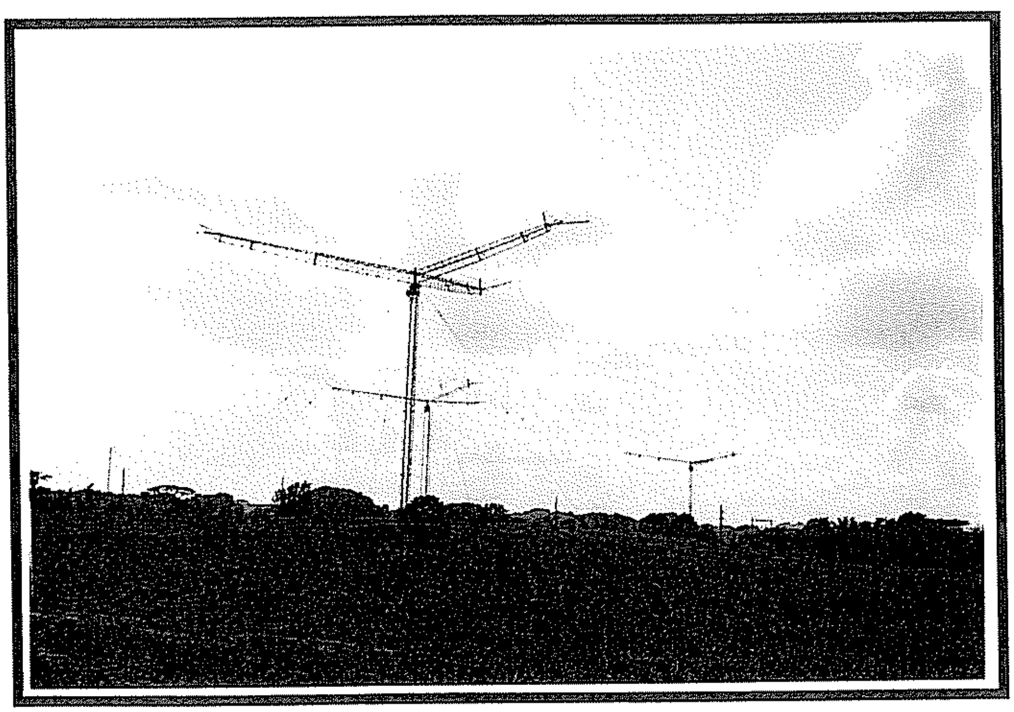


Figure 39. Above: View of Model LPH-24C log periodic antenna. This antenna system was installed at NSGA Northwest, Virginia, and Naval Radio Receiver Facility Salinas, Puerto Rico. Below: View of Model LPH-89 rotatable log periodic antenna installed at NRTF Isabela.

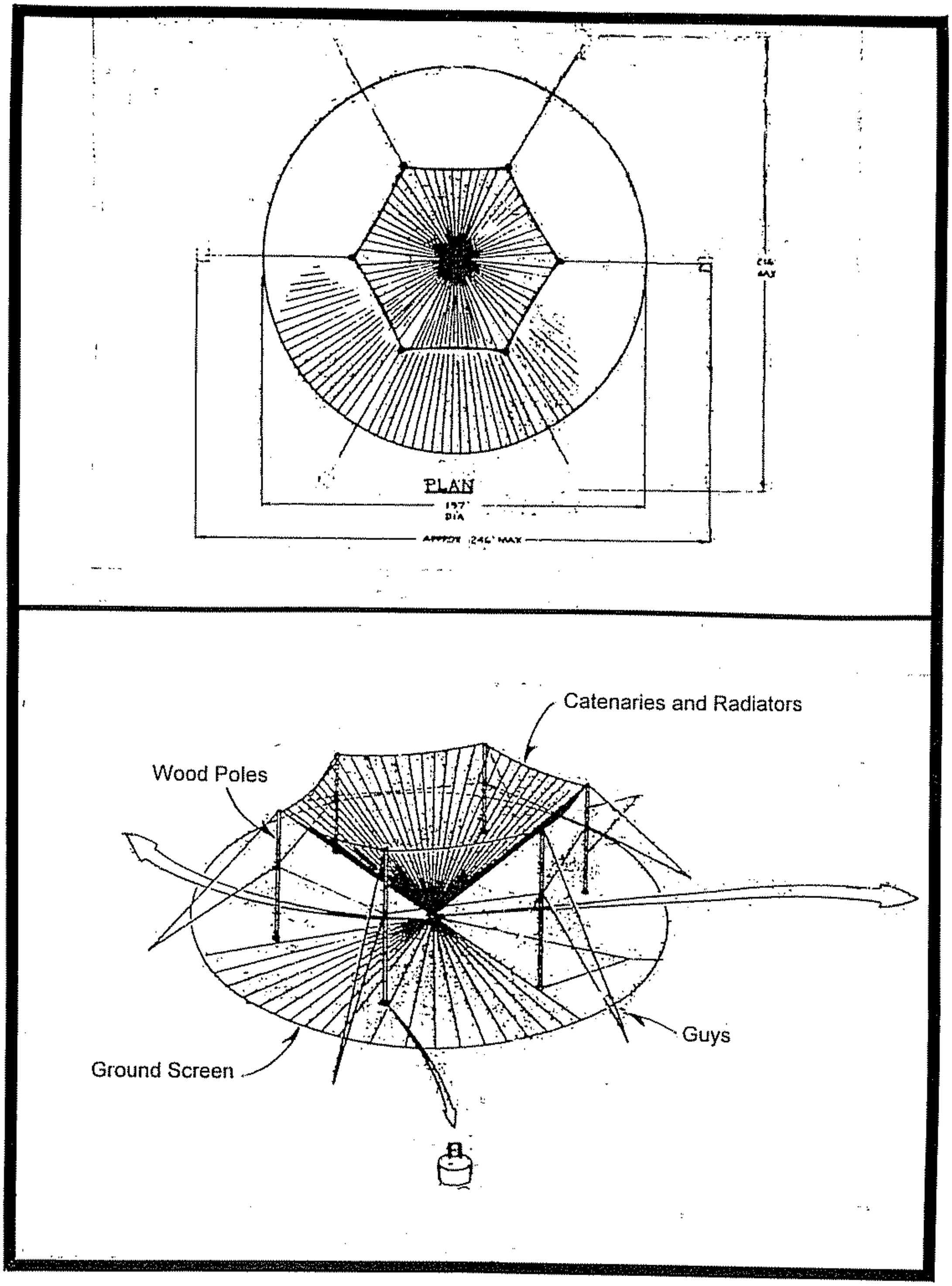


Figure 40. Above and below: Plan and isometric view of Model AS-2212/FRC, AS-2213/FRC, and AS-2214/FRC inverted cone antenna (Source: Naval Electronic Systems Command, Drawing No. RW66B307)

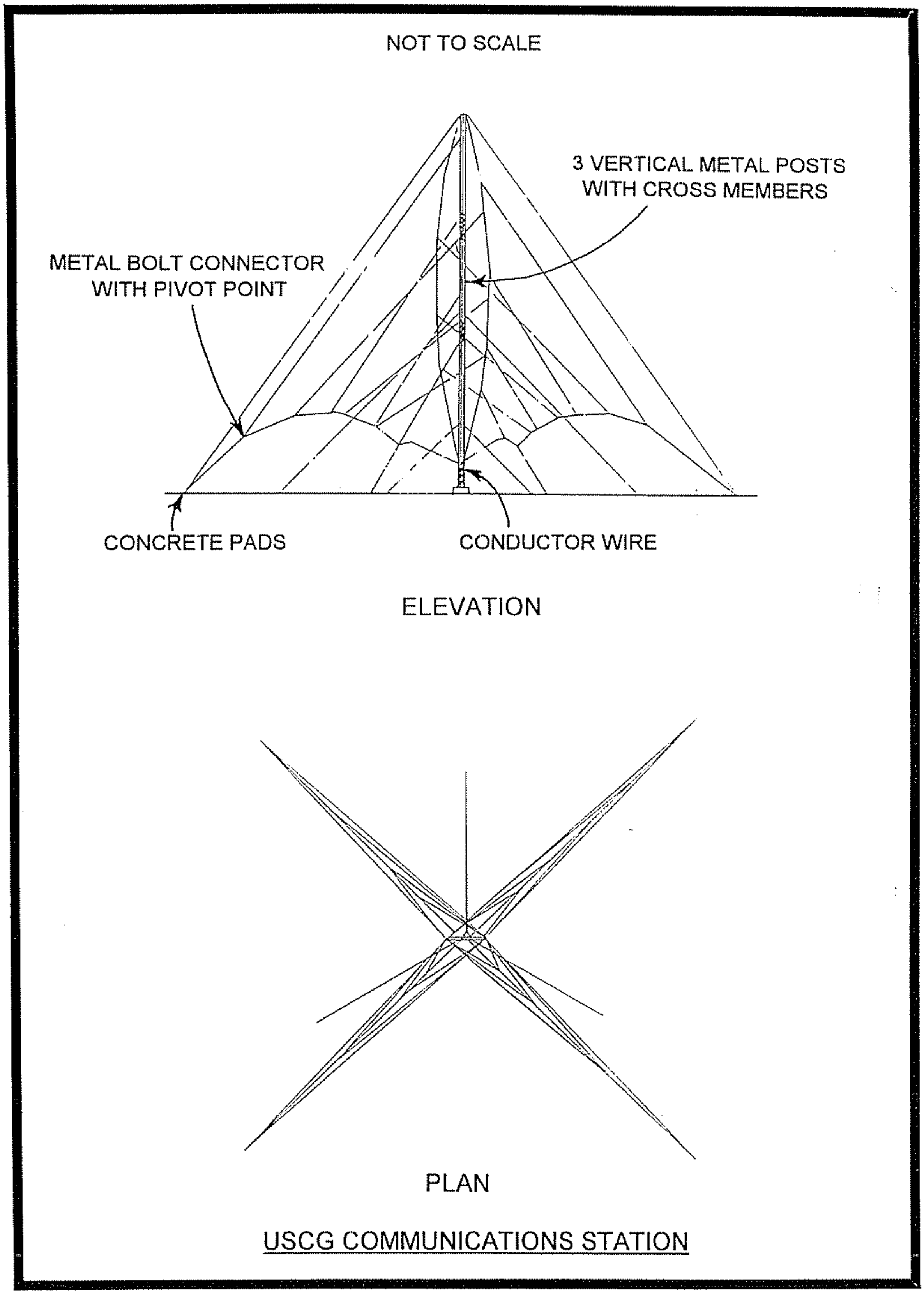


Figure 41. Above and below: Elevation and plan diagram of Model 530-3 omni transmitter antenna. This system is manufactured by Technology for Communications International (TCI) (Courtesy of USCG Communications Station, NSGA Northwest).

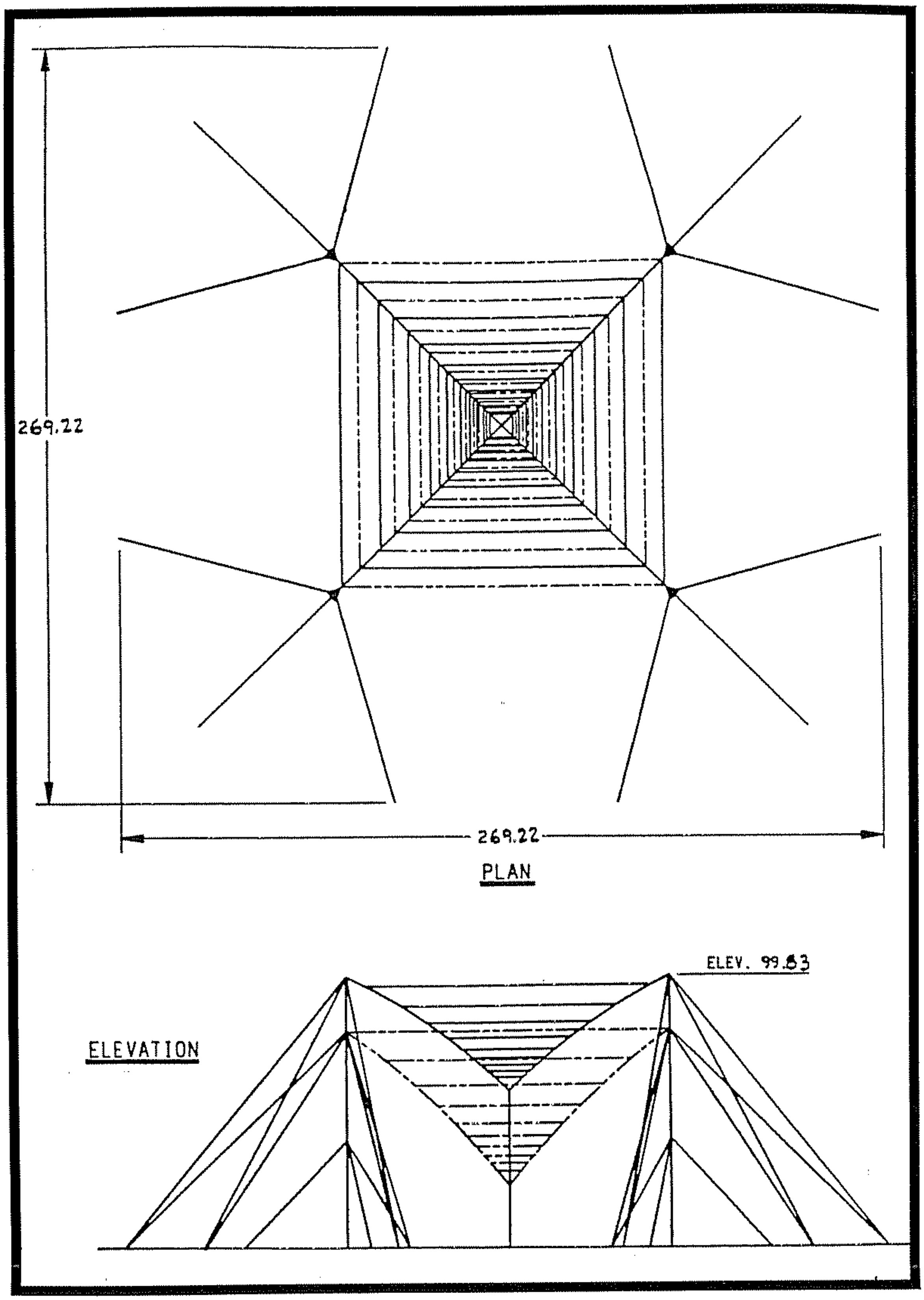


Figure 42. Diagram of TCI Model 540-2-05 Horizontal Omnidirectional Broadband Antenna (HOBA) (Taken from Technical Manual "TCI Model 540-2-05 Horizontal Omnidirectional Broadband Antenna", prepared by Technology for Communications International)

VHF/UHF/SHF SYSTEMS

Introduction

The radio frequency region above 30 MHz, from very high to extremely high frequencies, has been dedicated primarily to aircraft communications. This frequency spectrum is limited to line of sight, since these higher bands are not easily refracted by the atmosphere. The exception to this pattern is tropospheric scatter techniques that make possible an increased range. Tropospheric scatter systems are discussed earlier in this chapter. Line of sight propagation employs a transmitter antenna along a direct line with the receiving antenna. Line of sight is susceptible to interference from mountains and other obstacles, which degrades the signals.240

The VHF band (30-300 MHz) has a range of 25 to 30 miles, and is capable of transmitting a large amount of data using a small antenna. VHF applications include certain types of long-range radar systems, particularly those used for satellite surveillance.241 UHF signals (300-3,000 MHz) share similar advantages and disadvantages of VHF communications. However, an added benefit of the UHF region is that communication can be achieved via a relay satellite. UHF is well-suited for reliable, long range surveillance radar since it is free from weather interference. The UHF band also is used for tactical voice transmissions.242

The frequencies above the UHF band have been referred to as "micro-rays", "microwaves", and "super-high frequencies". The main advantage of SHF signals (3,000-30,000 MHz) is that they can be focused by a small dish antenna and directed into a narrow beam making them difficult to detect. The SHF band is well-suited for radar and satellite communications, which are discussed in separate sections.243

Evolution of VHF, UHF, and SHF Frequency Regions

In exploring the utility of the frequencies above the HF band, NRL conducted a series of experiments during the early 1920s to determine the upper frequency limits of the ionosphere in providing long-distance communications. In the early exploration of the VHF and UHF bands, it was observed that energy at these frequencies could be propagated to distances substantially beyond the optical horizon by means other than ionospheric refractions. By 1929, NRL had succeeded at developing the Navy's first VHF communications system, the Model XP transmitter. The transmitter, designed for continuous wave operation, was crystal controlled and incorporated three different stages of amplification. The Model XP equipments, which were installed on a number of ships and aircraft carriers, were used on ship-to-ship and ship-to-shore circuits throughout World War II to collect valuable propagation data.244 During the 1930s, the Navy invested on a large scale in additional VHF equipment, the Model TBS. This equipment was installed on many of the Navy's ships and served as an effective communications system during the war. The Model TBS remained in service for over a decade after the war.245

NRL also initiated R&D efforts with SHF frequencies in 1933; particular attention focused on developing transmitter power sources, which had always been a major impediment to exploring the higher frequency regions. Transmitting, receiving, and measurement equipment was developed and used in propagation investigations during the 1940s. By 1958, an operational system was made available and demonstrated. The high cost of the highly precise components, however, made the adoption of the system unfeasible at this stage. With the advent of solid-state technology, cheaper components made these systems a feasible and effective alternative.246

In 1938, the International Telecommunication Conference addressed the possibility of expanding communications into the ultrahigh frequency (UHF) range. UHF communications required the use of a shorter antenna as compared to VHF systems. NRL developed a broadband antenna (225-400 MHz), the "biconical" antenna, in 1942. Development of this system generated widespread interest and information on its design was distributed to several contractors engaged in providing the Navy with UHF equipment.247

During the 1950s, trends moved towards the use of frequencies above 30 MHz for short-range, ship-to-ship, and ship-to-plane communication. Early on it was assumed that radio waves in the VHF and UHF bands traveled along a line of sight path, and was limited to the horizon. Research revealed that radio waves travelling at these higher frequencies could be refracted and detected hundreds of miles beyond the horizon.248

SATELLITE SYSTEMS

Introduction

A satellite communications system uses satellites to relay radio transmissions between earth terminals. Satellites offer reliable, secure, and a cost effective method of telecommunications. Two types of communications satellites are employed: passive and active satellites. Passive satellites reflect radio signals back to earth. Active satellites serve as a repeater by amplifying the signal and retransmitting it back to earth; this increases the signal strength at the receiving terminal.249

A typical satellite communications link includes an active satellite and two or more earth terminals. One station transmits to the satellite on a frequency called the "UP-LINK" frequency. The satellite amplifies the signal, converts it to the "DOWN-LINK" frequency, and transmits it back to earth. Figure 43 illustrates a satellite handling several combinations of communications links simultaneously.250

Evolution of Satellite Systems

Up until the 1970s, the Navy relied on HF communications as the principal method of sending messages. By this date, however, the HF spectrum was overcrowded. Communications via satellite represented the next step in fulfilling the need for new and advanced long-range transmission methods.251

NRL initiated experiments using moon-reflected radio energy during the early 1950s. In 1951, the laboratory constructed the world's largest parabolic antenna at Stump Neck, Maryland. This antenna system was used successfully in July 1954 to transmit a human voice through outer space to the moon and back to earth. By the following year, NRL established transcontinental satellite communications from Washington, DC, to San Diego, California. In 1956, NRL expanded its satellite communications facilities with the construction of an "S-band facility" that employed a 60-foot steerable parabolic antenna. This facility was used to conduct many of NRL's original satellite experiments. Based on much of this research, the Navy established its first worldwide satellite communications system between 1964-1969. This system used the moon as a medium for passing messages between ships at sea and shore stations. The Navy's original system consisted of six ship and four shore installations, with satellite communication (SATCOM) earth terminals established at Cheltenham, Maryland; Wahiawa, Hawaii; Okinawa; and Oakhanger, England. Each station employed eighty-four foot diameter, steerable parabolic antennas.252

In 1960, the Defense Communications Agency (DCA) was established to oversee the satellite communications field. DCA was responsible for managing all of the long-haul, point-to-point circuitry for the worldwide military command and control systems. During the 1960s, most overseas communications were channelled across the Atlantic via one of two Intelsat satellites in permanent, geosynchronous high orbit. Ground bases to support the satellite traffic were established at Andover, Maine; Etam, West Virginia; Madley, Herefordshire; and, Goonhilly, Cornwall. By the end of 1967, NSA had constructed, under secret cover, two identical receiving stations at Winter Harbor, Maine and Sugar Grove, West Virginia. NSA also had established a secret annex at the U.S. Naval Communication Station at Asmera in Eritrea. Two signals centers were established at Port Lyautey in Morocco and Greece.253 Throughout the 1960s, the Satellite Communications Program expanded through collaborative efforts between private industries and military programs.254

In 1961, NRL established the Sugar Grove Satellite Communication Research Facility in Sugar Grove, West Virginia, to assist in space research projects. A 60-foot parabolic reflector was installed at this site during the mid-1960s. The dish was steered automatically using digital computer technology and was capable of achieving frequencies up to 4000 MHz. The parabolic reflector was attached to huge turntable tracks which rotated the dish upwards "not only to pick up strange sounds from outer space, but also echoes and signals from missiles and satellites".255 NRL subsequently designed and installed a 150-foot parabolic antenna at this site. NRL established the Waldorf Satellite Communication Research Facility in Waldorf, Maryland, in 1967. The facility contained a 60-foot parabolic antenna, a 25 kw transmitter, and support buildings to house the antenna and computer control, data processing, receiving and modem equipment, and laboratory space.256

NSA also relied on satellite communications to carry out their surveillance mission. NSA utilized a subseries of the SAMOS (Satellite and Missile Observation System) satellites that were used to photograph and televise pictures of missile bases, encampments, and other areas of interest. A series of "ferret" satellites were used by NSA as part of their electronic intelligence efforts. Ferret satellites monitor radio and radar signals from geosynchronous orbits in space, and are capable of picking up radio traffic of foreign military units, radar and telemetry data from missile tests, and private communications of foreign leaders.257

In 1971, the Navy's Fleet Satellite Communications System (FLTSATCOM) was approved. This system provided multi-channel UHF broadcast service to all Navy ships, as well as providing command and control links among shore stations, fleet ballistic missile submarines, aircraft carriers, and other ships and submarines. The original plans included four satellites in geostationary orbit to provide global coverage. These satellites, which were launched in 1978, were positioned over the Pacific, Atlantic, and Indian Oceans. The Navy's FLTSATCOM system is supported by satellite communications (SATCOM) earth stations.258

In April 1976, the U.S. Navy acquired its first operational ocean surveillance satellite system. The space and ground elements of the system were designated CLASSIC WIZARD, and the satellite portion was named WHITE CLOUD. By the 1970s, satellite communications technology began to supplant HF radio technology as the primary mode of military communications. Satellites became instrumental in performing a variety of intelligence missions, including imagery collection, SIGINT collection, communications, and early warning.259

Associated Property Types

The major components of a SATCOM earth terminal include an antenna, a receiver, a transmitter, and telemetry equipment. Earth terminal antennas are highly directional, high-gain antennas capable of transmitting and receiving signals simultaneously. Large parabolic antennas typically were used which ranged in size from ten-foot to sixty foot diameter dishes. All SATCOM earth terminals were equipped with highly sensitive receivers which were designed specifically to overcome down-link power losses and to permit extraction of the desired communications information from the weak received signal. All earth terminal transmitters generate high-power signals for transmission to the communications satellites. Transmitters used in earth terminals have output power capabilities that vary from 10 watts to 20 kw. Telemetry equipment is included in all communications satellite systems to permit monitoring of the operating conditions within the satellite.260

<u>AN/FSC-78 and AN/FSC-79 Earth Satellite Receiver Stations</u>

The AN/FSC-78 Earth Satellite Receiver Station provides one example of a SATCOM earth terminal facility. The SATCOM ground station was manufactured by the Ford Aerospace and Communications Corporation for use with Defense Satellite Communications System (DCSC) satellites (Figure 44). The AN/FSC-79 is a modified version of the AN/FSC-78. The first production contract for the Model AN/FSC-78 terminal was placed in 1974. The Defense

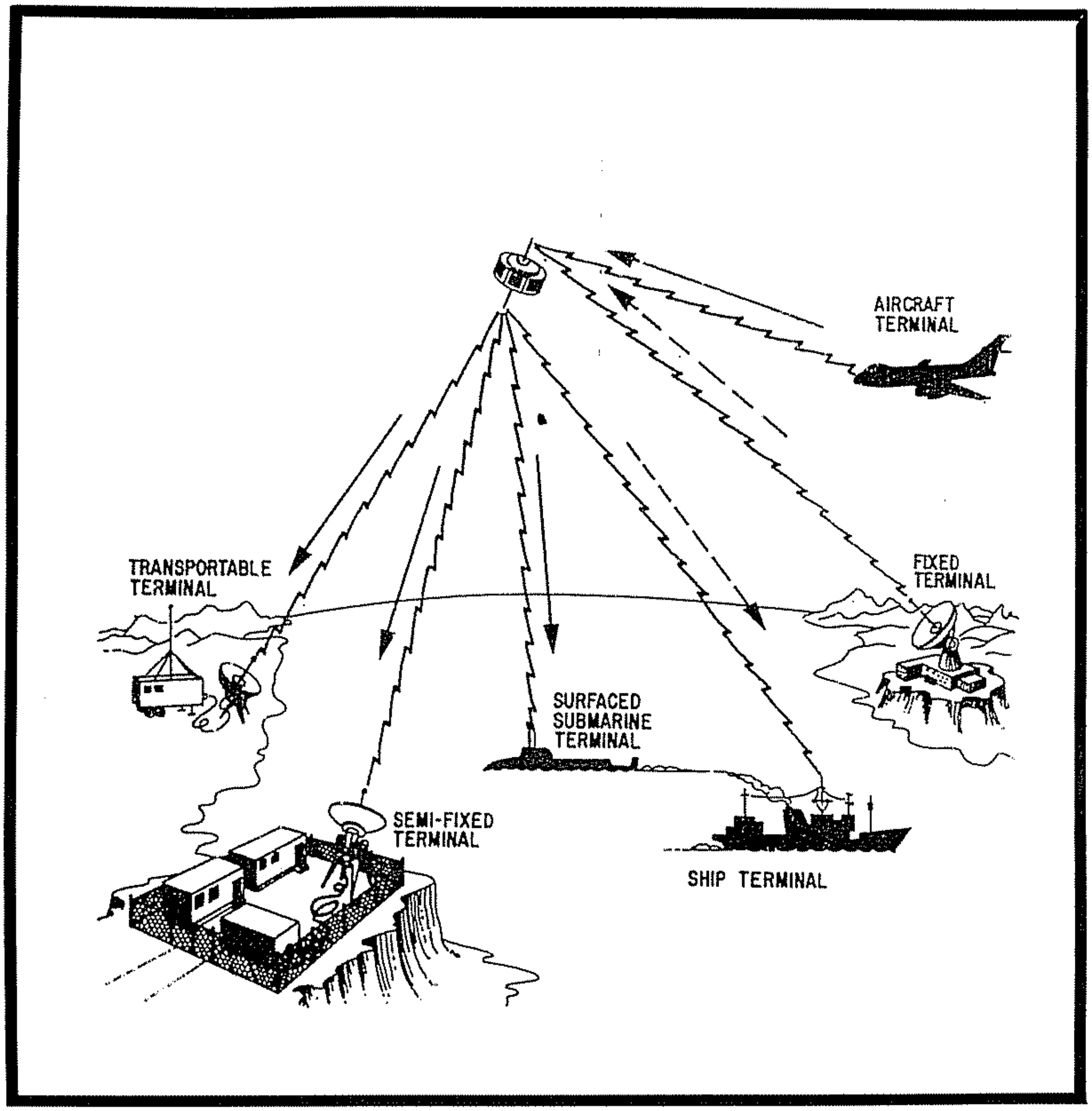
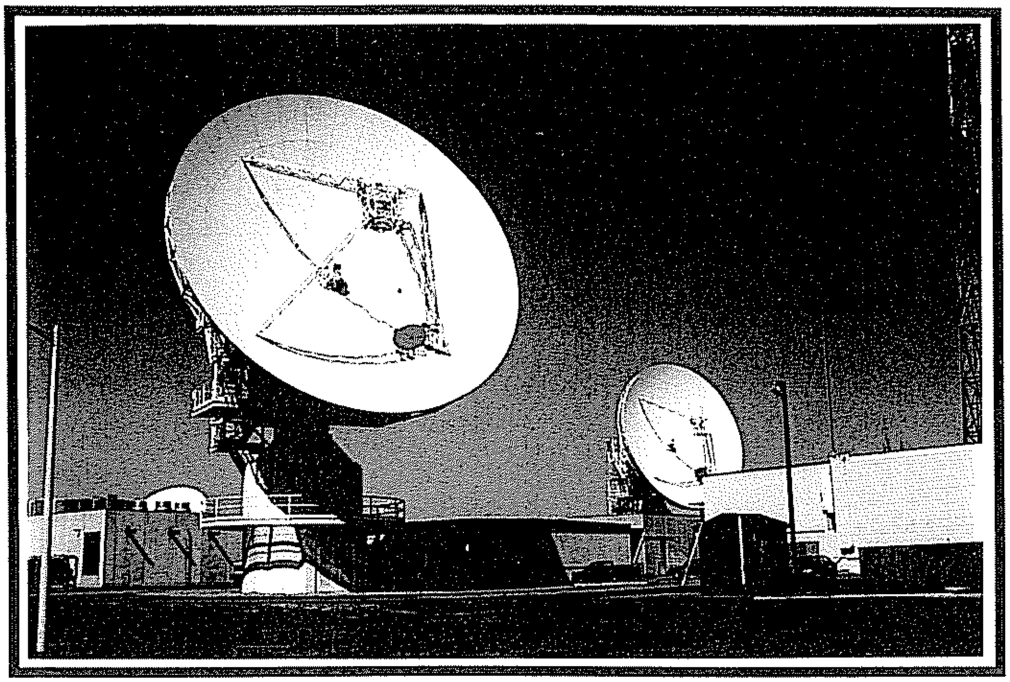


Figure 43. Diagram illustrating a satellite handling several combinations of communications links simultaneously (Taken from Navy Electricity and Electronics Series, "Radio-Frequency Communications Principles", 4-3).



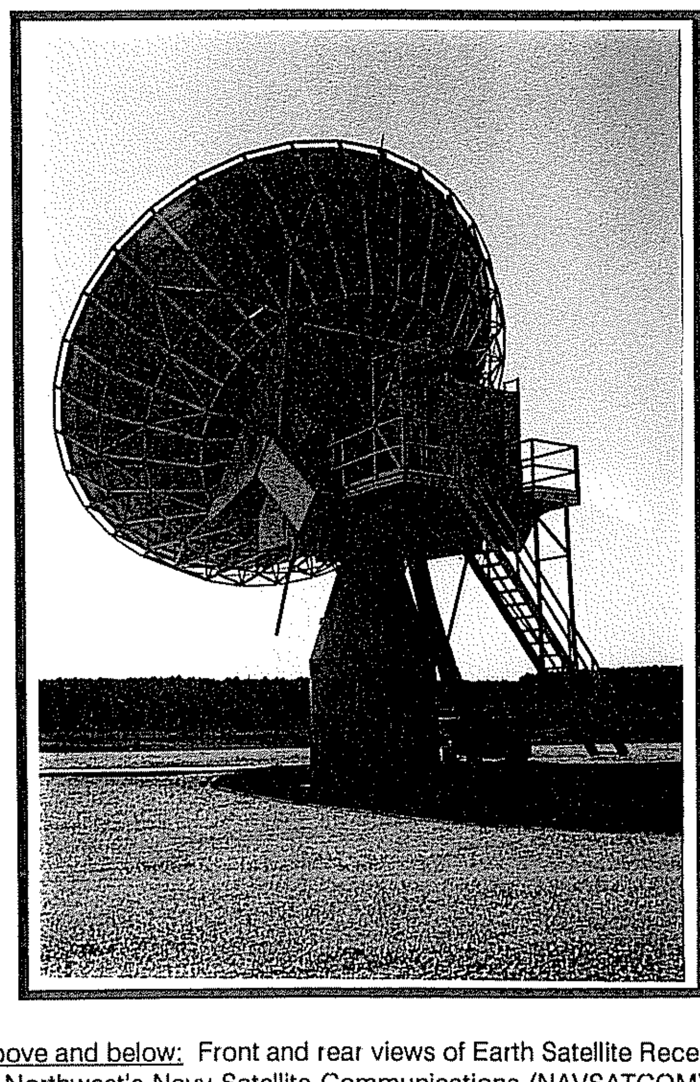


Figure 44. Above and below: Front and rear views of Earth Satellite Receiver Station installed at Northwest's Navy Satellite Communications (NAVSATCOM) complex.

Communications Agency (DCA), the U.S. Army, Navy, and Air Force acquired approximately 22 of these terminals in mid-1976 when operational test and evaluation began.[261]

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APPENDIX A

NAVY INSTALLATIONS ASSOCIATED WITH THE COLD WAR COMMUNICATION PROGRAM

APPENDIX A
NAVY INSTALLATIONS ASSOCIATED WITH THE NAVY'S COLD WAR COMMUNICATIONS PROGRAM

U.S. NAVAL COMMUNICATIONS STATIONS (NAVCOMSTA)--PRIMARY STATIONS

U.S. NAVAL COMMUNICATION STATION
BALBOA, CANAL ZONE

The naval radio station at Balboa was established in 1938 as part of the Naval Operating Base (NOB). When the Naval Communications System was established in 1950, six naval stations were designated as primary communication centers. These centers were located at Washington, D.C.; San Francisco, California; Pearl Harbor, Hawaii;, Guam; Balboa, Canal Zone; and, Port Lyautey, French Morocco. These stations furnished complete radio coverage over the major portions of the earth's strategic ocean areas.[1]

U.S. NAVAL COMMUNICATION STATION
GUAM

Under the Naval Communications System established in 1950, six naval stations were designated as primary communication centers. These centers were located at Washington, D.C.; San Francisco, California; Pearl Harbor, Hawaii;, Guam; Balboa, Canal Zone; and, Port Lyautey, French Morocco. These stations furnished complete radio coverage over the major portions of the earth's strategic ocean areas. The Naval Communications Area Master Station, Western Pacific, is the largest naval command on Guam, which serves the entire Western Pacific and Indian Ocean areas.[2]

U.S. NAVAL COMMUNICATION STATION
PEARL HARBOR, HAWAII

Under the Naval Communications System established in 1950, six naval stations were designated as primary communication centers. These centers were located at Washington, D.C.; San Francisco, California; Pearl Harbor, Hawaii;, Guam; Balboa, Canal Zone; and, Port Lyautey, French Morocco. These stations furnished complete radio coverage over the major portions of the earth's strategic ocean areas. The Naval Communication Area Master Station Eastern Pacific, Honolulu, was headquartered at the Wahiawa site. In 1980, the Wahiawa site represented the largest communication station in the world.[3]

U.S. NAVAL COMMUNICATION STATION
PORT LYAUTEY, FRENCH MOROCCO

Construction at Port Lyautey was initiated in October 1943 and included facilities for a Naval Communications Facility, Marine Barracks, Fleet Weather Central, Fleet Intelligence Center, Fleet Tactical Support Squadron 24, Naval Mobile Construction Battalion, Air Navigation Office, and Overseas Air Cargo Terminal.

When the Naval Communications System was established in 1950, six naval stations were designated as primary communication centers. These centers were located at Washington, D.C.; San Francisco, California; Pearl Harbor, Hawaii;, Guam; Balboa, Canal Zone; and, Port Lyautey, French Morocco. These stations furnished complete radio coverage over the major portions of the earth's strategic ocean areas. In January 1952, a Naval Air Station (NAS) Communication Center began transmitting general fleet broadcasts. The facility was disestablished in 1976 and replaced by satellite facilities. In December 1976, the radio receiver facility at Sidi Yahi was turned over to the Moroccans.[4]

U.S. NAVAL COMMUNICATION STATION SAN FRANCISCO, CALIFORNIA

Under the Naval Communications System established in 1950, six naval stations were designated as primary communication centers. These centers were located at Washington, D.C.; San Francisco, California; Pearl Harbor, Hawaii;, Guam; Balboa, Canal Zone; and, Port Lyautey, French Morocco. These stations furnished complete radio coverage over the major portions of the earth's strategic ocean areas.[5]

U.S. NAVAL COMMUNICATION STATION WASHINGTON, DC

Under the Naval Communications System established in 1950, six naval stations were designated as primary communication centers. These centers were located at Washington, D.C.; San Francisco, California; Pearl Harbor, Hawaii;, Guam; Balboa, Canal Zone; and, Port Lyautey, French Morocco. These stations furnished complete radio coverage over the major portions of the earth's strategic ocean areas.[6]

U.S. NAVAL COMMUNICATIONS STATIONS (NAVCOMSTA)--SECONDARY STATIONS

U.S. NAVAL COMMUNICATION STATION ADAK, ALASKA

Adak is an island situated along the Aleutian chain that separates the Bering Sea and the Pacific Ocean. During World War II, the Naval Operating Base (NOB) at Adak operated as the main ship-to-shore and point-to-point station, handling traffic within the sector and the U.S. mainland. In 1944, a central receiving station was constructed at Heart Lake, making Adak the major communications center for the entire area. Adak also served as a Joint Army-Navy Weather Center that provided weather forecasts and maintained detailed records.[7]

The majority of bases in the Aleutians were disestablished following World War II, however, the Adak and Kodiak stations continued to operate. The Naval Air Facility (NAF) at Adak was deactivated in 1949. That same year, the Navy acquired Davis Air Force Base and resumed air operations on August 1950. In 1951, the base was renamed Naval Station Adak.

The Naval Communications System designated secondary fleet and general broadcast stations when it was established in 1950. These stations were located at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines. The communication station established at Adak functioned as a separate entity from Naval Station Adak.[8]

U.S. NAVAL COMMUNICATION STATION BOSTON, MASSACHUSETTS

Under the Naval Communications System established in 1950, secondary fleet and general broadcast stations were established at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.[9]

U.S. NAVAL COMMUNICATION STATION CHARLESTON, SOUTH CAROLINA

Under the Naval Communications System established in 1950, secondary fleet and general broadcast stations were established at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.[10]

In July 1959, the Mine Base and the Naval Receiving Station were combined into one command, the U.S. Naval Station. The naval station functioned as a component activity of the Charleston Naval Base.[11]

U.S. NAVAL COMMUNICATION STATION
KODIAK, ALASKA

Under the Naval Communications System established in 1950, secondary fleet and general broadcast stations were established at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.[12]

U.S. NAVAL COMMUNICATION STATION
NEW ORLEANS, LOUISIANA

Under the Naval Communications System established in 1950, secondary fleet and general broadcast stations were established at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.[13]

U.S. NAVAL COMMUNICATION STATION
NEWPORT, RHODE ISLAND

Under the Naval Communications System established in 1950, secondary fleet and general broadcast stations were established at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.[14] The Newport, Rhode Island, station was disestablished in 1974.

U.S. NAVAL COMMUNICATION STATION
NEW YORK CITY, NEW YORK

Under the Naval Communications System established in 1950, secondary fleet and general broadcast stations were established at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.[15]

U.S. NAVAL COMMUNICATION STATION
NORFOLK, VIRGINIA

The radio station at Naval Base Norfolk was redesignated U.S. Naval Communication Station Norfolk in 1950. The existing facilities were were upgraded and expanded in response to its new mission This included construction of a new communication center (Building M-51), as well as a receiving station at Northwest, Virginia, and a transmitting station at Driver, Virginia. The Northwest and Driver sites were chosen because they were isolated and free from interference, which was critical to the overall performance of relaying radio signals. Construction at both sites was initiated during the early 1950s and followed standard policies adopted by the Bureau of Yards and Docks.[16]

U.S. NAVAL COMMUNICATION STATION
PHILADELPHIA, PENNSYLVANIA

Under the Naval Communications System established in 1950, secondary fleet and general broadcast stations were established at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.[17]

U.S. NAVAL COMMUNICATION STATION
SAN DIEGO, CALIFORNIA

Under the Naval Communications System established in 1950, secondary fleet and general broadcast stations were established at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.[18]

U.S. NAVAL COMMUNICATION STATION
SANGLEY POINT, PHILIPPINES

Under the Naval Communications System established in 1950, secondary fleet and general broadcast stations were established at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.[19]

The Sangley Point facility was established in March 1945 as a naval air base. A receiving facility at San Miguel and transmitting facilities at Bababantay and Moron were added to the Sangley Point facility in 1950.[20] The communication facility was disestablished in 1974.

U.S. NAVAL COMMUNICATION STATION
SAN JUAN, PUERTO RICO

Under the Naval Communications System established in 1950, secondary fleet and general broadcast stations were established at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.[21]

U.S. NAVAL COMMUNICATION STATION SEATTLE, WASHINGTON

Under the Naval Communications System established in 1950, secondary fleet and general broadcast stations were established at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.[22]

U.S. NAVAL COMMUNICATION STATION YOKOSUKA, JAPAN

Under the Naval Communications System established in 1950, secondary fleet and general broadcast stations were established at San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.[23]

U.S. NAVAL TRANSMITTER/RECEIVER STATIONS

NAVAL LOW FREQUENCY TRANSMITTER FACILITY AGUADA
AGUADA, PUERTO RICO

Three communications stations (Isabela, Aguada, and Salinas) were established to support the U.S. Naval Communication Station (NAVCOMSTA) at Roosevelt Roads. NAVCOMSTA is responsible for providing tactical communications to the Fleet; serving as the primary Defense Communication Agency (DCA) in Puerto Rico; and performing specialized duties relevant to communication research and engineering.[24]

The Naval Low Frequency Transmitter Facility (NLFTF), Aguada, was established in 1968 on the northwest coast of Puerto Rico. The low frequency transmitter facility was operational until 1974 when it was deactivated. However, in 1979, the facility was reactivated under a request by the Commander of Naval Operations, to offset the loss of a transmitter site in Balboa. NLFTF contains a 1,200-foot transmitter tower, transmitter building, emergency power plant building, and a helix house.[25]

U.S. NAVAL RADIO STATION ANNAPOLIS
ANNAPOLIS, MARYLAND

The Annapolis facility was established during World War I, across the Severn River from the Naval Academy, as a high-powered radio transmitting station. The site provided continuous duplex radio communication between the United States and France. When the Annapolis station became operational in September 1918, it utilized two 500-kw Poulson Arc Converter VLF transmitters built by Federal Telegraph Company of San Francisco. "At the time of its completion the Annapolis station was the most powerful one in the United States, with the exception of the one at New Brunswick, N.J., and was one of the most powerful in the world".[26]

The Annapolis station was upgraded during World War II with the installation of 50 kw LF transmitters. By this period, the radio station at Annapolis was the primary transmitting station for communication command and control, and operated one of the highest-powered transmitters in the world Throughout the war, all radio messages transmitted by the Navy Department, Washington, DC, to fleets at sea and overseas naval bases were sent through this station. The station's longest regular circuit throughout the war was with Pearl Harbor; messages for ships and stations beyond this point were relayed by the Navy's Oahu station.[27]

U.S. NAVAL RADIO STATION BELMAR
BELMAR, NEW JERSEY

The Naval radio station at Belmar, New Jersey, served as the headquarters for the Navy's transatlantic communication system established during World War I.

U.S. NAVAL RADIO STATION (T) CUTLER
CUTLER, MAINE

During the late-1940s, the Navy's communications planners realized the need for a very high power, very low frequency (VLF) radio transmitter to broadcast to the North Atlantic and Arctic. In 1956, Congress appropriated the funds to purchase a 2,850-acre peninsula in Cutler, Maine. The Naval Communications Unit Cutler occupies nearly 3,000 acres in the town of Cutler along the northern coast of Maine. The site was ideal for locating the massive antenna system required for a VLF installation. Construction was initiated in January 1958 and largely completed by January 1961. The station was commissioned formally on 23 June 1961.[28]

The VLF transmitter installed at the Cutler site was capable of handling two million watts of power. Two other antenna arrays were constructed at this site, which were composed of thirteen, 800-foot to 900-foot towers and 75 miles of phosphorous bronze wire. The station also constructed its own power plant to handle the power needs.[29]

U.S. NAVAL RADIO TRANSMITTER FACILITY DRIVER
DRIVER, VIRGINIA

The Naval Radio Transmitter Facility (NRTF) Driver was officially opened in 1955 as part of the U.S. Naval Communication Station Norfolk. A transmitter building and associated antenna field were constructed to support this mission. The antenna field consisted of four 300-foot towers, one 800-foot tower, and one 220-foot tower. These antenna systems connected the installation with Naval Radio Receiving Station, Northwest and the communications center located at Norfolk Naval Base. The transmitter building served as the central operations building and contained all the transmitter equipment. By 1958, NRTF Driver had 46 operating transmitters. In 1976, 71 transmitters were in operation, the highest number in the history of the installation. Transmitter equipment was being upgraded constantly between 1960 and 1994.[30] NRTF Driver was disestablished in 1994.

U.S. NAVAL RADIO TRANSMITTER FACILITY ISABELA
ISABELA, PUERTO RICO

Three communications stations (Isabela, Aguada, and Salinas) were established to support the U.S. Naval Communication Station (NAVCOMSTA) at Roosevelt Roads. NAVCOMSTA is responsible for providing tactical communications to the Fleet; serving as the primary Defense Communication Agency (DCA) in Puerto Rico; and performing specialized duties relevant to communication research and engineering.[31] The transmitter and receiver systems at Isabela and Salinas were established in 1963

The Naval Radio Transmitter Facility (NRTF), Isabela, was established in northwestern Puerto Rico as a high frequency transmitter site. The operations core contains seven buildings surrounded by an array of antennas.[32]

U.S. NAVAL RADIO STATION KEY WEST
KEY WEST, FLORIDA

Under the Naval Communications System established in 1950, six naval stations were designated as primary communication centers. Secondary fleet and general broadcast stations also were established and included facilities in San Juan, Puerto Rico; Key West, Florida; New Orleans, Louisiana; Charleston, South Carolina; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; Newport, Rhode Island; Boston, Massachusetts; San Diego, California; Seattle, Washington; Kodiak and Adak, Alaska; Yokosuka, Japan; Sangley Point, Philippines.[33]

U.S. NAVAL RADIO STATION (T) MARE ISLAND
MARE ISLAND, CALIFORNIA

The Naval Radio Station Mare Island became operational in 1904 as a transmitter station to ships at sea as well as to shore commands in the Pacific. The station's original mission was to provide the then new Marconi wireless circuits to fill the Navy's requirements in the San Francisco Bay area. By 1915, Mare Island had built all of the radio stations that spanned the Pacific Coast from Point Loma (San Diego) to the Pribilof Rocks (Bering Sea).

In 1917, Naval Communication Station San Francisco moved its headquarters and receiver site from Mare Island to Yerba Buena Vista. The transmitter site, however, remained at Mare Island. A new transmitter site was constructed at Dixon, California. This resulted in the closure of the Mare Island transmitter site in 1966.[34]

U.S. NAVAL RADIO STATION (R) NORTHWEST
CHESAPEAKE, VIRGINIA

The U.S. Naval Radio Station (R) Northwest was established in 1951 to provide radio receiving services for commands in the Norfolk naval complex, including relaying messages from ships at sea and communication bases throughout the world. The facility was not equipped to originate radio messages. The initial construction campaign was largely completed by 1953 and included a receiver building (Building 14), a 355-foot receiver tower (Building 18), and a one-mile circular antenna field. The antenna array consisted of 57 antennas which could be aimed in different directions to pick up radio signals from all parts of the world. The tower relayed the signals, on microwave lengths, to the Norfolk Naval Base. The installation was commissioned in January 1954 and activated in May 1955. In April 1956, the installation initiated monitoring operations in support of Communication Security (COMSEC).[35]

Northwest's mission was expanded in January 1958 with the establishment of an AN/GRD-6 High Frequency Direction Finding (HFDF) Station. In September 1971, the Naval Radio Station (R) Northwest became a component activity of the Naval Communication Station (NAVCOMMSTA). In 1972, a NATO Satellite Communications (SATCOM) terminal was constructed to support one of Northwest's new tenant activities, the Defense Satellite Communication System (DSCS). The Coast Guard also operated as one of Northwest's tenant organizations. The facility was designed to service all ships east of the Mississippi to Europe, and from the Arctic to the Gulf of Mexico. Northwest became independent of the Norfolk Naval complex in 1975 when it was redesignated as the Naval Security Group Activity (NSGA) Northwest.[36]

U.S. NAVAL RADIO STATION SABANA SECA
SABANA SECA, PUERTO RICO

The U.S. Naval Magazine, Sabana Seca was established in 1939 when the U.S. Government condemned roughly 2,032 acres along the northern coast for a naval ammunition depot. Following World War II, the Sabana Seca ammunition depot was decommissioned and placed in "caretaker status." In 1949, a Navy Radio Receiver Facility (RRF) was located at the North Tract of Sabana Seca. Soon after, the facility was redesignated the U.S. Naval Communication Station, Sabana Seca in March 1952.

During the 1960s, the Navy established a number of Naval Security Group Activity (NSGA) installations to operate High Frequency Direction Finding (HF-DF) ground communications and surveillance systems. The primary mission of these facilities was to provide communications-related support including communications relay, communications security, and communications manpower to Navy and other Department of Defense elements. These facilities, which were established throughout the United States and overseas, gathered information from enemy communications, radars, or from enemy missile tests.[37] Sabana Seca was selected as one of the overseas sites. A Circularly Disposed Antenna Array (CDAA) was constructed to support this new mission. Nine years later, the facility was redesignated as the U.S. Naval Security Group Activity (NSGA), Sabana Seca.

U.S. NAVAL HIGH FREQUENCY RECEIVER FACILITY SALINAS
SALINAS, PUERTO RICO

Three communications stations (Isabela, Aguada, and Salinas) were established to support the U.S. Naval Communication Station (NAVCOMSTA) at Roosevelt Roads. NAVCOMSTA is responsible for providing tactical communications to the Fleet; serving as the primary Defense Communication Agency (DCA) in Puerto Rico; and performing specialized duties relevant to communication research and engineering.[38] The transmitter and receiver systems at Isabela and Salinas were established in 1963. Salinas operated as a high-frequency (HF) receiver site until 1976, when it was relocated to NSGA Sabana Seca.

The Salinas site contains an operations building surrounded by an antenna field. The antenna field includes a variety of antenna systems, including a conical monopole antenna, spiracone antennas, rotatable log periodic antennas, and a rosette antenna.

U.S. NAVAL RADIO STATION SAN DIEGO
SAN DIEGO, CALIFORNIA

The U.S. Naval Radio Station Point Loma was established in May 1906 as part of the Navy's first radio communications network system. Between 1906 and 1908, the station participated in a number of projects that contributed significantly to radio broadcasting. The station was involved in experiments conducted by Dr. Lee DeForest in radio telephone communications from the USS *Connecticut*.[39]

In July 1914, the Navy acquired an additional 73.6 acres at Chollas Heights, approximately fifteen miles east of Point Loma. Two years later, the Navy completed construction of a high power radio transmitting station on this site. The installation was expanded further during the 1920s when the original Point Loma facility was converted to a receiver site. The headquarters and message center were relocated to the Naval Base Headquarters building in San Diego.[40]

During World War II, Naval Radio Station San Diego played a vital role in wartime communications. The station's Chollas Heights transmitters relayed the first message to Washington of the Pearl Harbor attack; the main transmitters on Hawaii went down temporarily during the attack. In 1941, the station acquired an additional 145 acres at Imperial Beach and two years later completed construction of a new receiver facility at this site. Activities conducted at the original Point Loma facility were relocated here.[41]

In 1947, the Secretary of the Navy established the Naval Communication Station, Eleventh Naval District, as a separate activity under a commanding officer. In 1953, Naval Communication Station San Diego was established as a completely separate command. The facility was upgraded with new state-of-the-art communication systems throughout the 1960s and 1970s. In 1965, a "Wullenweber" antenna was constructed at the receiver site at Imperial Beach. In 1966, the installation became part of a world-wide Automatic Digital Network (AUTODIN) of computers capable of secure, virtually error-free message transmission at extremely high speeds. The facility was updated again in the mid-1970s with the installation of Local Digital Message Exchange (LDMX), and new computers and copiers. In 1980, the Remote Information Exchange Terminal (RIXT) became operational. This system provided the latest state-of-the-art in optical scanning, video display control, automatic logging, and high speed transmission and reception.[42]

U.S. NAVAL RADIO STATION (R) WINTER HARBOR
WINTER HARBOR, MAINE

The Winter Harbor receiving station has its origins in the World War I era Otter Point, Mount Desert Island transmitter site. In the mid-1930s, the Navy bowed to local pressure and dismantled the Otter Point facility, transferring its activities to Winter Harbor. The station was commissioned on February 28, 1935 with Chief Radioman Max Gunn in charge. By the time of Pearl Harbor the station had about forty operators on duty.[43]

During World War II, the radio station at Winter Harbor operated as an element within a larger communications network. Physical expansion of the facility during this period included the construction of a wooden barracks, mess hall, sick bay, and administration building. The original receiving building also was expanded. The Winter Harbor facility, along with other high-frequency direction finders along the Atlantic coast, reported bearings taken from aircraft, surface ship, and submarine transmissions to a control center in Maryland; the data was then transmitted to the Naval Intelligence's Section's Atlantic Division.[44]

In 1944, the station was reclassified as a Supplementary Radio Station to the Communication Station, Boston, but continued its service as a radio receiving station. Due to its excellent reception capacity, the Winter Harbor installation remained in service after World War II. It was redesignated U.S. Naval Security Group Detachment, U.S. Naval Radio Station (R), Winter Harbor, in 1950. The facility served as a satellite operation to the Boston-based naval communications center. During the early-1950s, Quonset huts had been erected to house the influx of personnel. In 1961, the Navy acquired an additional 400 acres near the village of Corea for construction of a new direction-finding facility, the "Wullenweber" Circularly Disposed Antenna Array (CDAA), to replace the old remote station at Seawall. In 1958, the Winter Harbor installation was redesignated Naval Security Group Activity (NSGA) Winter Harbor. Facilities were erected for the station's participation in the Classic Wizard Advanced Tactical Ocean Surveillance System, and as the center for the training of all personnel involved, worldwide, in the systems' maintenance and operation.[45]

NAVAL SECURITY GROUP ACTIVITY (NSGA) FACILITIES: DOMESTIC SITES

NAVAL SECURITY GROUP ACTIVITY ADAK, ALASKA

See U.S. NAVAL COMMUNICATION STATION, ADAK, ALASKA

NAVAL SECURITY GROUP ACTIVITY CHARLESTON, SOUTH CAROLINA

See U.S. NAVAL RADIO STATION CHARLESTON, SOUTH CAROLINA

NAVAL SECURITY GROUP ACTIVITY KEY WEST, FLORIDA

See U.S. NAVAL RADIO STATION KEY WEST, FLORIDA

NAVAL SECURITY GROUP ACTIVITY HOMESTEAD, FLORIDA

A number of NSGA installations were established by the Navy to operate High Frequency Direction Finding (HF/DF) ground communications and surveillance systems. The primary mission of these facilities was to provide communications-related support including communications relay, communications security, and communications manpower to Navy and other Department of Defense elements. These facilities, which were established throughout the United States and overseas, were tasked with gathering information from enemy communications, radars, or from enemy missile tests.[46] Domestic sites were established at Charleston, South Carolina; Key West, Florida; Homestead, Florida; Sugar Grove, West Virginia; and, Winter Harbor, Maine.

NAVAL SECURITY GROUP ACTIVITY NORTHWEST CHESAPEAKE, VIRGINIA

See U.S. NAVAL RADIO STATION NORTHWEST

NAVAL SECURITY GROUP ACTIVITY SAN DIEGO

See U.S. NAVAL COMMUNICATION STATION, SAN DIEGO, CALIFORNIA

NAVAL SECURITY GROUP ACTIVITY SKAGGS ISLAND

The Naval Security Group Activity (NSGA) Skaggs Island was established in 1941 when the Navy purchased 3,300 acres for the Naval Radio Station, San Francisco Receiving Unit. It was designated a NSGA facility in July 1962. The facility's mission is to receive incoming messages from fleet and naval shore installations in the Pacific areas. It provides communications, research and development, and support for sea-air rescue operations.[47] The facility was disestablished in 1976.

NAVAL SECURITY GROUP ACTIVITY SUGAR GROVE
SUGAR GROVE, WEST VIRGINIA

A number of NSGA installations were established by the Navy to operate High Frequency Direction Finding (HF/DF) ground communications and surveillance systems. Domestic sites were established at Charleston, South Carolina; Key West, Florida; Homestead, Florida; Sugar Grove, West Virginia; and, Winter Harbor, Maine. The primary mission of these facilities was to provide communications-related support including communications relay, communications security, and communications manpower to Navy and other Department of Defense elements. These facilities, which were established throughout the United States and overseas, were tasked with gathering information from enemy communications, radars, or from enemy missile tests.[48]

NAVAL SECURITY GROUP ACTIVITY WINTER HARBOR
WINTER HARBOR, MAINE

See U.S. NAVAL RADIO STATION WINTER HARBOR

NAVAL SECURITY GROUP ACTIVITY (NSGA) FACILITIES: OVERSEAS SITES

NAVAL SECURITY GROUP ACTIVITY EDZELL
EDZELL, SCOTLAND

The Navy established a number of Naval Security Group Activity (NSGA) installations to operate High Frequency Direction Finding (HF-DF) ground communications and surveillance systems. The primary mission of these facilities was to provide communications-related support including communications relay, communications security, and communications manpower to Navy and other Department of Defense elements. These facilities, which were established throughout the United States and overseas, gathered information from enemy communications, radars, or from enemy missile tests.[49]

Overseas sites were established in Edzell, Scotland; Sabana Seca, Puerto Rico; and Karamursel, Turkey. The Edzell, Scotland facility was acquired by the Navy in 1960; formerly, the site was operated as a U.S. Air Force radio facility. The main interception equipment located at this facility included an AN/FLR-12 circular antenna system, which measured 1,640 feet in diameter and 66 feet high. Targets for the antenna system included detecting Soviet naval activity in the North Sea and troop and armor movement in Eastern Europe and the Soviet Union.[50]

NAVAL SECURITY GROUP ACTIVITY KARAMURSEL
KARAMURSEL, TURKEY

The Navy established a number of Naval Security Group Activity (NSGA) installations to operate High Frequency Direction Finding (HF-DF) ground communications and surveillance systems. The primary mission of these facilities was to provide communications-related support including communications relay, communications security, and communications manpower to Navy and other Department of Defense elements. These facilities, which were established throughout the United States and overseas, gathered information from enemy communications, radars, or from enemy missile tests.[51] Overseas sites were established in Edzell, Scotland; Sabana Seca, Puerto Rico; and Karamursel, Turkey. The facility in Karamursel, Turkey was acquired by the Navy in 1965; prior to this, the site was operated by the U.S. Air Force. A field of rhombic antennas and an AN/FLR-9 antenna system were constructed to support the Navy's new mission. These antenna systems were used to monitor communications from Soviet air and naval activity in the Black Sea area and Soviet missile testing activities. The Black Sea served as the Soviet's training ground for both new equipment and operational doctrine. Encrypted messages intercepted at the site were transmitted to NSA headquarters in Fort Meade, Maryland for analysis. By the early 1970s, the facility's main function was to track Soviet naval traffic in the western Black Sea and the Dardanelles area. In 1975, Karamursel was shut down by Turkey in response to an arms embargo imposed on Turkey.[52]

NAVAL SECURITY GROUP ACTIVITY ROTA
ROTA, SPAIN

Rota is located twenty miles north and across from the port of Cadiz in southwestern Spain. Naval Station Rota was officially commissioned in November 1957.

**NAVAL SECURITY GROUP ACTIVITY SABANA SECA
SABANA SECA, PUERTO RICO**

See U.S. NAVAL RADIO STATION SABANA SECA

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APPENDIX B

THE U.S. NAVY'S COLD WAR COMMUNICATION SYSTEMS

APPENDIX B

THE U.S. NAVY'S COLD WAR COMMUNICATIONS SYSTEMS

The following list includes communications systems developed and operated by the U S. Navy. The list is organized according to the following categories:

(1) search radars;
(2) direction finders (D/F);
(3) tropospheric scatter systems;
(4) extremely low frequency (ELF)/very low frequency (VLF)/low frequency (LF) systems;
(5) high frequency (HF) systems;
(6) very high frequency (VHF)/ultrahigh frequency (UHF) systems; and
(7) satellite systems

The Navy's shore-based communications systems are designated by the "AN" nomenclature system. The letters AN are followed by a slant bar and three additional letters (i.e., AN/GPS-56). These letters indicate where the equipment is to be installed (aircraft, missile, ship), the type of equipment (radar, countermeasures), and the purpose of the equipment (weapon control, navigation, detection). For shore-based communication systems, the first letter would consist of a "G" indicating a ground-type installation. The second letter may include "P" for radar or "R" for radio, which indicates the type of equipment. The third letter may include "C" for communications, "D" for direction finder, "R" for receiving/passive detection, "S" for detection and/or range bearing, or "T" for transmitting.[1]

SEARCH RADARS

AN/FPS-7 Radar

Type: Surveillance

Description: The Model AN/FPS-7 search radar is manufactured by General Electric and consists of a very high power L-band (1,250-1,350 MHz) monopulse 3-D search radar. Search range is approximately 500 km and height coverage is up to 45,000 meters. The transmitter utilizes a high power klystron capable of delivering 10 MW of power.[2] This radar system is part of the SAGE network.

AN/FPS-8 Radar

Type: Surveillance

Description: The Model AN/FPS-8 search radar is manufactured by General Electric and is a medium power L-band search radar designed for aircraft control and early warning. The system has been installed at commercial airports and military bases both in the United States and overseas. In most cases, the antenna is exposed and is mounted on a tower. In harsher climates, the antenna is protected by a radome.[3] This radar system is part of the SAGE network.

AN/FPS-17 Radar

Type: Surveillance

Description: The Model AN/FPS-17 detection radar was designed by General Electric to detect intermediate-range missiles. The AN/FPS-17 radar works in tandem with the Model AN/FPS-79 tracking radar. Once a detection radar indicates that a missile test or space launch has occurred, the tracking radar is activated. The AN/FPS-79 "swings its white, round face in a noiseless arc in the same direction, ready to track the missiles along their course".[4] This system is used for ELINT operations.

AN/FPS-117 Radar

Type: Surveillance

Description: The Model FPS-117 radar is based on the latest solid state electronics. The system is equipped with an FPS 117V5 radar manufactured and designed by General Electric. This radar provides tricoordinated data (i.e., distance, direction, and altitude) and has a range of up to 250 nautical miles (nm). The radar relies on sophisticated computer equipment which processes data, controls transmission power and radar beams, adjusts the equipment to prevailing conditions (e.g., weather, landscape), supplies information on conditions, and calibrates the equipment. The FPS117 radar system is widely used outside the United States, such as in Germany, Saudi Arabia, and South Korea.[5]

Over-the-Horizon (OTH) Radar

Type: Surveillance

Description: Most surface-based radars are limited in range to the radar horizon. Over-the-Horizon Radars (OTH) are the exception. OTH radar systems transmit low-frequency (LF) beams that follow the curvature of the earth and utilize the ionosphere as a reflector OTH radars, as a result, are capable of detecting moving targets (i.e., aircraft and missiles) at distances and altitudes beyond line-of-sight distances. The broad beams that this system generates can only provide warning, not tracking capabilities. OTH systems are used in strategic defense and surveillance roles to detect incoming aircraft, cruise missiles, and ships at sea.[6]

The first OTH radar was developed by NRL in 1954 and was known as "Music". This system was used to detect both atomic explosions and missile launchings.[7] Between 1956 and 1958, NRL conducted additional work to develop the high-power (100 kw-5 MW) "Madre" radar, which stood for "magnetic drum radar equipment." The Madre represented the first OTH radar to detect low-velocity targets at ranges out to 1000 miles. The radar consisted of a large, fixed antenna measuring 300 feet wide by 140 high and a smaller, steerable reflector antenna. The operations building contained the transmitter and the receiving, data-processing, and display equipment.[8]

During the 1980s, Raytheon Corporation developed a Relocatable-Over-the-Horizon Radar (ROTHR) system for the U.S. Navy. ROTHR is a tactical, bi-static ionospheric backscatter system designed to provide wide area surveillance of both aircraft and ships. The system consists of a transmitter site, a receiver site, and an operations center. The transmitting and receiving sites are separated by about 50-100 nautical miles (nm). The control center provides instructions to the transmitter site to direct radar illumination. The receiver site takes the returned beams and forms them digitally in the signal processor; it also carries out the range and Doppler processing and extracts the target detections. The detections are then passed to the operations center.[9]

Over-the-Horizon-Backscatter (OTH-B) radars are used in strategic defense and surveillance roles.

Most of these radar systems are located within the U.S. borders to detect incoming aircraft, cruise missiles, and ships at sea. OTH-B radars utilize the high frequency radio band. OTH-B radars are capable of detecting a target from 600 to 2,500 mile range. This system has several disadvantages. OTH-B radars utilize relatively long-wavelength signals and are not able to distinguish separate targets that are close together. This radar system also relies on very large antennas to transmit the long-wavelength, high-power signals. Other drawbacks are that the system is relatively easy to jam and is sensitive to disturbances in the atmosphere, such as strong magnetic fields that are encountered near the North and South poles.[10]

DIRECTION FINDERS (D/F)

AN/GRD-6 Improved HFDF Antenna

Type: HF-DF
Description: This system was developed by NRL in 1958 as a self-sustaining broadband sleeve antenna to reduce "octangular" error of direction finder. The system was manufactured by Sylvania.[11]

AN/FRD-10 Wide-Aperture HFDF Circularly Disposed Antenna Array (CDAA)

Type: HF-DF; Reconnaissance
Description: NRL developed the first U.S. wide-aperture, circularly disposed radio direction finder (Model AN/FRD-10) in 1957. This system, manufactured by Sylvania/Radiation Systems, provided greatly improved direction-finding bearing accuracy. The Model AN/FRD-10 was installed at the Naval Research Lab in Hybla Valley, Virginia, where it was used to determine the orbit of the Russian satellite, Sputnik I, in 1957 The system was installed at stations throughout the world. The Model AN/FRD-10 circularly disposed antenna array (CDAA) can be used for two general purposes: (1) all-purpose communications receiving antenna and (2) direction finding capability. The network they form is used to intercept and correlate information from a variety of signal sources.[12] This system, commonly referred to as the "Wullenweber" antenna array, consists of four concentric rings, including a high frequency (HF) and low frequency (LF) antenna and associated reflector screens. The reflecting screens are formed by a row of lower metal poles. An operations building is located at the center of the antenna array, and consists of a two-story, windowless structure.

AN/FLR-9 Circularly Disposed Antenna Array (CDAA)

Type: HF-DF; ELINT
Description: The AN/FLR-9, referred to as an "Elephant Cage", was manufactured by Philco/Sylvania to serve as a countermeasure receiver set. The system consists of three arrays, each comprised of a ring of antenna elements around a circular reflecting screen. An operations building is located in the center of the array and contains the electronic equipment for aiming the directional beams for monitoring and direction-finding. The entire system measures about 900 feet in diameter. An underground tunnel connects the antenna array to the operations building.[13] This system was installed at NAVSECGRU's Karamursel, Turkey, site and was used to monitor communications from Soviet air and naval activity in the Black Sea area. Encrypted messages intercepted at the site were transmitted to NSA headquarters in Fort Meade, Maryland, for analysis. Karamursel also monitored various Soviet missile and space launches.

AN/FLR-12 Circularly Disposed Antenna Array (CDAA)

Type: HF-DF
Description: An AN/FLR-12 circular antenna system was installed at the NSGA Edzell, Scotland, facility. The system measured 1,640 feet in diameter and 66 feet high and was

used to detect Soviet naval activity in the North Sea, and troop and armor movement in Eastern Europe and the Soviet Union.[14]

TROPOSPHERIC SCATTER SYSTEMS

DYE-5 Site

Type: Tropospheric Scatter
Description: Between 1954 and 1969, NRL conducted investigations of surface-to-surface tropospheric scatter propagation to test its feasibility for Naval communications.[15] An example of this type of system is the Dye-5 Site, commonly referred to as "Elephant Ears", located at the Naval Air Station (NAS) Keflavik, Iceland. This system was constructed between 1961 and 1962, and was part of a network of similar sites that extended across the North American continent, from Greenland to the United States and continued on to Turkey and Greece. The system consisted of a very powerful 50 kw transmitter that sent signals to a similar site in Greenland. The transmitter system continued to "hop", through a series of transmitter sites, until it reached its destination. Signals were directed into four, 120-foot high parabolic dishes which, in turn, amplified the signal millions of times (50 m KW). Each of the parabolic dishes is supported by a steel-frame superstructure. Riveted metal panels comprise the parabolic dish. The signal also was squeezed down to produce a very narrow, powerful beam. These signals were transmitted at an angle of .8 degrees, allowing them to clear the horizon and transmit into space until it reaches the troposphere (approximately 40 miles). The signals are then "scattered" into millions of pieces and reflected down to earth. These reflected particles are detected by another 120-foot parabolic dish until it receives a usable signal.[16]

This system represented state-of-the-art technology for its time, and illustrated the evolution of communications systems from the ionospheric to tropospheric range. The system consists of four concave, parabolic antenna dishes arranged with two facing each other. Each antenna is supported by a steel-frame superstructure. The system is now obsolete.

ELF/VLF/LF SYSTEMS

AN/FRT-72 LF Transmitter

Type: LF
Description: The Model AN/FRT-72 LF Transmitter was manufactured by Continental Electronics. It consists of three, 800-foot steel towers and its associated "Marconi Triatic" array. Two sets of wires extend from the top of each tower; each wire then spreads into four radiating wires to form a wide band system. Each set of wires connects to the adjacent tower forming a "triatic array". A feed line extends from the midsection of one of the wide bands to the power source, or helix house. Two of the towers operate at one frequency, and the third tower operates at another frequency.

AN/FRT-87 VLF Transmitter

Type: VLF
Description: This system was designed and manufactured by Continental Electronics. It consists of a 1,200-foot tower and nine 600-foot support, or guide, towers. The antenna array extends from the top of the 1,200-foot tower and radiates outward to the guide towers. The main feed line extends from the helix house to three different heights along the 1,200-foot tower. Messages transmitted via the VLF system run through 4 1/2-inch thick copper wire. The Model AN/FRT-87 VLF transmitter is capable of communicating with submerged submarine 50 to 60 feet below the surface.[17] This system was installed at NRTF Annapolis in 1969; the system is scheduled for removal as a result of the facility's closure.

HF SYSTEMS

Conical Monopole HF Antenna

Type: HF, Omni-directional
Description: The Naval Research Laboratory (NRL) developed this new antenna system in 1957 to meet the requirement for a low height, high-frequency (HF) antenna. An important design consideration was to minimize obstruction to landing aircraft at naval air stations. A major advantage of this system was that it permitted power to be fed through a grounded base and did not require a separate HF transformer like most other systems developed by this date. Hundreds were installed at both Air Force and Navy air stations.[18]

The conical monopole antenna consists of a number of radiating elements attached to the top of a central conducting support pole. The support pole is formed by three vertical posts connected by cross members. The radiating elements extend outward and downward to a point just below the pole's midpoint. The elements then extend downward and inward to a connecting ring at the base of the pole. Connecting cross-members extend from the midpoint of the pole outward to the vertical radiating members; these members form an "impedance transformer". Diagonal support wires are attached to the midsection of the antenna array and extend to the ground; ceramic insulators are installed on these support wires. The antenna is fed at a point between the ring and the pole.[19]

Hy-Gain Model CM-2002 Conical Monopole Antenna

Type: HF, Omni-directional
Description: The Model CM-2002 conical monopole manufactured by Hy-Gain Electronics Corporation is similar in configuration to the NRL-designed antenna described above. The system is an omni-directional, HF communications antenna that operates over a frequency range of 2.5 to 10 megacycles. The system can be used as both a high-power transmitting or receiving antenna. Due to its low angle radiation patterns, the system can be used for both sky wave medium and long range operations, as well as ground wave short range communications.[20]

Rhombic Antenna Systems

Type: HF
Description: A rhombic antenna consists of a wire several feet off the ground and attached to four posts in the shape of a diamond. Each side is approximately ten feet long. One end of the wire is attached to a coaxial cable that runs underground to a centrally located operations building.[21]

Model LPH HF-24C Log Periodic Antenna

Type: HF
Description: The Model LPH HF-24C Log Periodic Antenna was developed during the 1970s. The system consists of a "fish-shaped" antenna formed by a cylindrical metal post enclosed by two metal cages. Four diagonal support wires extend from the top of the pole

and are secured at ground level. The antenna array is attached to the top of the metal pole which functions as a radiating arm. The array consists of a series of radiating, or telescoping, elements. A large metal "fin" is secured to one end of the antenna array. The array elements decrease in size and spacing toward the fin.

Hy-Gain Model LP-1110 Log Periodic Antenna

Type: Omni-directional, HF
Description: The Model LP-1110 log periodic antenna manufactured by Hy-Gain Electronics Corporation is similar in configuration to the Model LPH HF-24C described above. The system is an omni-directional, HF communications antenna that operates over the frequency range of 6.5 to 30 megacycles.

Model LP-1504 Log Periodic Antenna

Type: Horizontally-polarized, HF
Description: The Model LP-1110 log periodic antenna was manufactured by Hy-Gain Electronics Corporation as a horizontally-polarized, HF communications system. The system operates in the frequency range of 3 to 40 MHz, and can be used in the transmitting or receiving mode. The structure consists of two, 140-foot steel towers supporting the antenna array. The antenna array consists of two catenaries that are attached to the top of each tower; these wires extend in front of the tower to the ground. Horizontal radiating elements are strung in between the two catenaries, forming the antenna screen.

Model LP-0500 Log Periodic Antenna

Type: Horizontally-polarized, HF
Description: The Model LP-0500 log periodic antenna is a horizontally-polarized, fixed station system used for medium range communications in the 2 to 30 MHz frequency region. The structure consists of two steel-frame support towers with the antenna array extending from the top of the towers down to the ground.

Model 530 Short Range Log Periodic Antenna

Type: HF
Description: The Model 530 was manufactured by Technology Communications International (TCI) and is designed specifically to support reliable short range communications, and transmits its radio energy straight overhead using the *sky wave* propagation method. This antenna system is used for shore-to-ship and ground-to-air communications. Previously, ships had to communicate with distant stations. Due to the high take-off angle (HTOA) of this system, ships can now communicate with nearby stations.[22]

Model 532 Improved Medium Range Log Periodic Antenna

Type: HF
Description: The Model 532 was manufactured by Technology Communications

International (TCI). The system is specifically designed to serve as a medium range communications system, capable of operating within 230 to 1,600 miles.[23]

Model LPH-89 Rotatable Log Periodic (RLP) Antenna

Type: HF
Description: The Model LPH-89 rotatable log periodic (RLP) antenna consists of a T-shaped configuration comprised of a central tower supporting three steel-frame arms. Guy wires extend from the top and midsection of the central tower. Radiating wires extend from the T-shaped horizontal members to form a web configuration.

Model 505-102 Inverted Cone Antenna

Type: HF, Omni-directional
Description: The Model 505-102 inverted cone antenna was developed during the late-1960s. The system consists of six vertical wood posts arranged in a circular configuration. Guy wires extend from the top and midsection of the posts to the ground. The antenna array, which is connected to a horizontal guide wire attached to the top of the posts, is formed by radiating diagonal elements that extend downward and inward to the midpoint of the array. The upper portion of each array element is comprised of two wires that form a triangular shape and then extend down along a single wire.

Model 4202-AA Inverted Discone Antenna

Type: HF, Omni-directional
Description: The Model 4202-AA inverted discone antenna manufactured by Hy-Gain Electronics Corporation is an omni-directional, HF communications system. The system operates over a frequency range of 2.5 to 32 megacycles. The antenna system is used as both a high-power transmitting and receiving antenna. The structure consists of 60 vertical radiators supported by 65-foot tall wooden poles. The vertical radiators terminate in a feedring assembly located at the center of the circular array. The antenna incorporates a ground screen of copper radials.[24]

Model AS-2212/FRC, AS-2213/FRC, and AS-2214/FRC Inverted Cone Antenna

Type: HF, Omni-directional
Description: The Model AS-2212/FRC, AS-2213/FRC, and AS-2214/FRC inverted cone antenna is similar in configuration to the Model 505-102 described above. The system consists of six vertical wood posts arranged in a circular configuration. The antenna array is comprised of 30, 600-foot radiating elements that are attached to a horizontal guide wire installed along the top of the vertical wood posts. These elements extend downward and inward to the midpoint at the interior of the circular array. The upper portion of each array element is comprised of two wires that form a triangular shape and then extend down along a single wire.

Model 530-3 Omni Transmitter Antenna

Type: HF
Description: The antenna system consists of a central frame formed by three separate posts arranged in a triangular layout and connected by diagonal cross members. A conductor wire is located within the vertical metal pole. The antenna array consists of a series of vertical wires and diagonal wires that extend from the top of the antenna structure. The diagonal arrays extend to four separate points to form a cross-shaped configuration. The outermost, diagonal radiating elements extend to the ground and are attached to a concrete pad. The other diagonal radiating elements extend downward and are attached to a horizontal guide wire near the base; support wires with insulators extend from the horizontal guide wire and are secured to the ground.

Model TCI-612B Loop Arrays

Type: MF
Description: "Loop Arrays" (Model TCI-612B) consist of three arrays arranged in an arched, T-shaped configuration. The two arch-shaped arrays and intersecting array each consist of eight loops. Each loop antenna consists of a low metal, oval-shaped element attached to a low concrete pier. An underground PVC conduit extends along one side of the loop arrays which contains electrical wiring that connects to a central box.

HF Broadband Spiral Antenna (Models 570-1-02C and 570-1-03C)

Type: HF
Description: The HF Broadband Spiral Antenna (Models 570-1-02C and 570-1-03C) is manufactured by Technology for Communications International, Mountain View, California. The Model 570-1-02C is a four-arm dual mode receive antenna, and the Model 570-1-03C is a four-arm dual mode transmit antenna. Both systems have a frequency range of 2 to 30 MHz and are capable of operating at both short and long-range HF circuits using the ionospheric (sky wave) propagation. Both systems are defined by a pyramidal configuration. The central tower consists of a triangular metal support with diagonal cross-members. Six main wire members are attached at the top of the central pole and extend downward and outward forming a triangular array. Horizontal members are strung between the vertical members.

High Take-Off Antenna (HTOA)

Type: HF
Description: The HTOA system consists of a main, triangular-shaped metal pole with four radiating wires attached at the top of the tower. These array elements extend downward and outward to the ground. A series of diagonal array elements extend from various points along the tower and are attached at the base by a common wire.

Model 540-2 Horizontal Omnidirectional Broadband Antenna (HOBA)

Type: HF
Description: The Model 540-2 HOBA Antenna was developed during the 1990s and is manufactured by Technology for Communications International, Mountain View, California.

This antenna system is a horizontally polarized, omniazimuthal HF communications antenna. This "state-of-the-art" antenna system is capable of operating two channels at the same time. The HOBA antenna consists of four, 99-foot galvanized steel towers which support the two radiating arrays. The radiating arrays, or curtains, are fabricated from "Alumoweld" wire. Diagonal antenna elements attached at the top of each post extend inward and downward to a central point. Horizontal members connect the diagonal members, forming an inverted pyramid configuration. A series of guy, or support, wires extend from three points along each metal post and extend to the ground.

SATELLITE SYSTEMS

AN/FSC-78 Radar

Type: Earth Satellite Receiver Station
Description: The AN/FSC-78 was developed in 1974 as a semi-fixed satellite communication (SATCOM) ground station. The system was manufactured by the Ford Aerospace and Communications Corporation, and was designed for use with Defense Satellite Communications System (DCSC) satellites. The first production contract for the terminal was placed in 1974. The Defense Communications Agency (DCA), the U.S. Army, Navy, and Air Force acquired approximately 22 up to mid-1976 when operational test and evaluation began.[25]

AN/FSC-79 Radar

Type: Earth Satellite Receiver Station
Description: The AN/FSC-79, developed during the 1970s, is a modified version of the AN/FSC-78. The terminal was manufactured by the Ford Aerospace and Communications Corporation and has been supplied to the U.S Navy to support Navy fleet broadcast.[26]

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APPENDIX C

U.S. NAVY ACTIVE SHIP FORCE LEVELS, 1946-1989

APPENDIX C
U.S. NAVY ACTIVE SHIP FORCE LEVELS, 1946 – 1989

The following tables were compiled by the Department of the Navy's Naval Historical Center from the following sources: Navy Directory; Annual Reports of the Secretary of the Navy; Comptroller of the Navy (NAVCOMPT); Department of the Navy 5-Year Program, Ships & Aircraft Supplemental Data Tables (SASDT); and Office of the Chief of Naval Operations (OP-802K) Ship Management Information Systems.

The five tables list the types and numbers of Navy vessels in operation during the decades from 1940 to 1980. A brief summary of important events is included at the bottom of each table, which is intended to tie the increases and/or decreases in ship force levels to broader historical events.

Ship Force Levels, 1940s

	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949
Battleships	15	17	19	21	23	23	10	4	2	1
Carriers, Fleet	6	7	4	19	25	28	15	14	13	11
Carriers, Escort	--	1	12	35	65	71	10	8	7	7
Cruisers	37	37	39	48	61	72	36	32	32	18
Destroyers	185	171	224	332	367	377	145	138	134	143
Frigates	--	--	--	234	376	361	35	24	12	12
Submarines	64	112	133	172	230	232	85	80	74	79
SSBNs	--	--	--	--	--	--	--	--	--	--
Command Ships	--	--	--	--	--	--	--	--	--	--
Mine Warfare	27	29	36	135	323	586	112	55	54	52
Patrol	34	20	19	100	515	1204	119	74	50	50
Amphibious	--	--	121	673	2147	2547	275	107	86	60
Auxiliary	116	210	392	564	993	1267	406	306	273	257
Surface Warships	237	225	282	635	827	833	226	198	180	174
Total Active	478	790	1782	3699	6084	6768	1248	842	737	690

Historical Highlights: Naval Communication Service reorganized in 1942; separate section formed to accommodate expanding role of communication intelligence (COMINT). By World War II, U.S. Navy established chain of D/F stations from Iceland to South America. Navy's shore and ship D/F systems crucial in defeating German submarine menace. World War II ends 8 May 1945. Substantial military build-up faced major reductions following World War II. By 1947, U.S. armed forces reduced by 90 per cent. U.S. provided military aid to Greece and Turkey in 1947. Marshall Plan launched in 1948 to revive western European economies. U.S. became NATO member in 1949.

Ship Force Levels, 1950s

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
Battleships	1	3	4	4	4	3	3	2	--	--
Carriers, Fleet	11	17	19	19	20	21	22	22	24	23
Carriers, Escort	4	9	10	0	7	3	2	--	--	--
Cruisers	13	15	19	19	18	17	16	16	15	12
Destroyers	137	206	243	247	247	249	250	253	245	237
Frigates	10	38	56	56	57	64	70	84	71	61
Submarines	72	83	104	108	108	108	108	113	109	109
SSG/SSBNs	--	1	1	2	2	1	2	2	2	4
Command Ships	--	--	--	--	--	--	1	1	1	1
Mine Warfare	56	91	114	121	117	112	113	104	77	82
Patrol	33	40	29	23	22	15	11	12	12	6
Amphibious	79	208	189	226	223	175	139	134	121	120
Auxiliary	218	269	309	287	288	262	236	224	213	205
Surface Warships	161	262	322	326	326	333	339	355	331	310
Total Active	634	980	1097	1122	1113	1030	973	967	890	860

Historical Highlights: U.S.-U.S.S.R. relations deteriorate 1945-1950. Korean War begins 25 June 1950. Armistice signed in 1953. During 1950s, U.S. Navy patrolled North Atlantic shipping lanes to Europe and Mediterranean for NATO By this date, U.S. had established extensive surveillance system and collection network, including ground stations, aircraft, ships, and submarines. During early 1950s, naval communications stations worldwide underwent major construction program. Naval Communication System formed in 1950; responsible for providing communication between CNO and principal fleet, area, and force commanders. Naval Communication System consisted of network of primary, secondary, and inactive stations.

Ship Force Levels, 1960s

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Battleships	--	--	--	--	--	--	--	--	1	1
Carriers	23	24	26	24	24	25	23	23	23	22
Cruisers	13	12	13	18	24	27	29	35	35	34
Destroyers	226	223	240	222	215	221	217	216	219	201
Frigates	41	41	68	40	40	39	42	46	50	43
Submarines	106	105	104	102	102	104	104	105	105	100
SSG/SSBNs	7	10	14	17	23	30	37	41	41	41
Command Ships	1	1	1	2	2	2	2	2	2	2
Mine Warfare	81	83	84	84	84	84	84	83	84	74
Patrol	4	4	2	--	--	--	--	3	6	7
Amphibious	113	110	130	132	133	135	159	162	157	153
Auxiliary	197	206	218	216	212	213	212	216	210	207
Surface Warships	280	276	321	280	279	287	288	296	304	279
Total Active	812	819	900	857	859	880	909	931	932	885

Historical Highlights: Defense Intelligence Agency (DIA) created in 1961 to consolidate activities of different military branches. Cuban Missile Crisis 1962. Vietnam conflict 1963–1973. U.S. troops entered Vietnam by 1963. Dramatic fall in ship numbers evident between 1968-1969; due to decision to limit use of American military force in Vietnam and de-commissioning of many World War II-era ships.

Ship Force Levels, 1970s

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Battleships	--	--	--	--	--	--	--	--	--	--
Carriers	19	19	17	16	14	15	13	13	13	13
Cruisers	31	30	27	29	28	7	26	26	28	28
Destroyers	155	152	132	139	119	102	99	92	95	97
Frigates	47	61	66	71	64	64	64	64	65	65
Submarines	103	100	94	84	73	86	74	77	81	80
SSG/SSBNs	41	41	41	41	41	41	41	41	41	41
Command Ships	--	--	--	--	--	--	--	--	--	--
Mine Warfare	64	59	31	34	34	34	25	25	25	25
Patrol	15	17	16	14	14	14	13	6	3	3
Amphibious	97	95	77	65	65	64	65	65	67	67
Auxiliary	171	177	153	148	135	123	116	114	113	114
Surface Warships	249	262	225	239	211	193	189	182	188	190
Total Active	743	752	654	641	587	570	536	523	531	533

Historical Highlights: By 1970s, whole series of signals intelligence, ocean surveillance, and nuclear detection stations established by different military branches (i.e., Air Force Electronic Security Command and NSGA command). Last U.S. forces withdraw from South Vietnam following cease fire in 1973. South Vietnam falls to North Vietnamese communists in 1975. Following Vietnam War, U.S. intelligence community affected by series of budget cuts. By 1985, defense build-up underwent steady decline.

Ship Force Levels, 1980s

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Battleships	--	--	--	1	2	2	3	3	3	4
Carriers	13	12	13	13	13	13	14	14	14	14
Cruisers	26	27	27	28	29	30	32	36	38	40
Destroyers	94	91	89	71	69	69	69	69	69	68
Frigates	71	78	86	95	103	110	113	115	107	100
Submarines	82	87	96	98	98	100	101	102	100	99
SSBNs	40	34	33	34	35	37	39	37	37	36
Command Ships	3	4	4	4	4	4	4	4	4	4
Mine Warfare	25	25	25	21	21	21	21	22	22	23
Patrol	3	1	4	6	6	6	6	6	6	6
Amphibious	63	61	61	59	57	58	58	59	59	61
Auxiliary	110	101	117	103	120	121	23	127	114	137
Surface Warships	191	196	202	195	203	211	217	223	217	212
Total Active	530	521	555	533	557	571	583	594	573	592

Historical Highlights: Grenada operation 1983. Attempted peacekeeping operations in Lebanon 1983. Fall of Berlin Wall 1989.

APPENDIX D

TECHNICAL GLOSSARY AND KEY TO ABBREVIATIONS

APPENDIX D

TECHNICAL GLOSSARY AND KEY TO ABBREVIATIONS

Antenna: Conductor or system of conductors for radiating or receiving radio waves, exclusive of the means for connecting its main portion with associated apparatus.

Array: Arrangement of several individual antennas spaced in such a way as to give desired directional characteristics. That is, their individual contributions to the antenna pattern add or strengthen signals in one or more preferred directions while canceling signals in other directions. The individual antennas in an array are referred to as "elements" of an array.

Antenna coupler: Radio-frequency transformer used to connect antenna to transmission line, or to connect transmission line to radio receiver.

Cipher or Code: Methods used to transform the original text (plaintext) of a message to a form of unintelligible to all except those possessing the original version of the cipher or code key (keylist or codebook). Ciphers are used to transform plaintext units of regular length; codes are used to transform units of variable length.

Communication center: An agency charged with the receipt, transmission, and delivery of messages. It typically includes a message center, a cryptographic section, radio transmitter facilities, and radio receiver facilities. Transmitter, receiver, and relay stations are not necessarily located in the communication center, however, facilities for their remote control are housed there.

Communications intelligence: Communications intelligence (COMINT) includes the interception of transmissions, such as radio, telephone, video, and facsimile traffic. COMINT can be collected from the air waves, cables, fiber optics, or any medium, and can include coded and uncoded messages.

Cryptanalysis: Transforming an intercepted message from ciphertext to plaintext without having possession of the original version of the cipher key. Referred to as "code breaking".

Cryptology: Science of deriving information from the electromagnetic spectrum. Includes signals intercepting, identifying, recording, direction finding, fingerprinting of transmitter characteristics, cryptanalysis, and the analysis of electromagnetic signal parameters in order to provide intelligence. Cryptology is usually limited in its application to the use of radio frequencies of the electromagnetic spectrum.

Decryption: Transforming the ciphertext of a message back into plaintext using the original version of the cipher or code key.

Dipole antenna: System composed of two equal electric charges of opposite sign, separated by a finite distance.

Directional antenna: Antenna which, due to its construction, radiates or receives radio waves better in some directions than others.

Direction finder: Radio receiving device used to determine the direction along which radio waves are arriving from a receiver.

Doppler radars: This radar system is used to determine azimuth and relative velocity; these systems are not used to calculate range. The oscillator, which generates a steady signal at a constant frequency, picks up changes in frequency when it comes in contact with a moving target. For example, the target is approaching if the echo is at a higher frequency than the signal.

Electronic intelligence: Electronic intelligence (ELINT) mainly encompasses the interception and analysis of noncommunication transmissions, such as radar and telemetry. For example, analyzing the emissions of a fire control radar enables an analyst to infer the capabilities of the gun or missile associated with the radar Identifying the location of a radar, in and of itself, is useful since it may indicate the location of enemy forces

Electronic signal monitoring: Signals are collected by passive receivers and recording devices, or electronic signal monitoring (ESM) equipment. Ground forces utilize vehicle-mounted receiver arrays. ESM arrays also are employed on combat aircraft and warships.

Encryption: Transforming of the plaintext of a message to ciphertext using the original version of a cipher or code key.

Extremely high frequency (EHF): EHF is the band of frequencies from 30 to 300 GHz. EHF signals require very small antennas for transmission and reception. A major benefit of EHF communications is that the transmission path can be made very narrow, thus limiting enemy interception. EHF band is well-suited for communications relay satellites.

Extremely low frequency (ELF): The ELF band covers the radio frequency spectrum up to 300 hertz. ELF communications consists of a very long wavelength of energy that permits a very slow transmission of information. ELF signals are useful in communicating with submarines, since the communications can penetrate deep below the ocean surface.

Ferret satellites: Ferret satellites monitor radio and radar signals from geosynchronous orbits in space, and are capable of picking up radio traffic of foreign military units, radar and telemetry data from missile tests, and private communications of foreign leaders.

Groundwave path: Signals travel through the earth's surface. These signals are short-ranged but have the advantage of being able to travel around hills and other obstacles.

High frequency (HF): HF is the band of frequencies from 3 to 30 MHz. The HF band is widely used by the military for long-range radio transmissions. HF signals require minimal amounts of transmitting energy to be transmitted great distances. Signals transmitted in the HF region can be cheaply sent from a small, low-power whip-antenna to receivers all over the world. Long-range HF bands utilize the ionospheric layer of the atmosphere, making them vulnerable to disruptions such as nuclear explosions, humidity, and seasonal effects. HF transmissions also can be easily intercepted and jammed.

Ionosphere: Outer layer of electronically charged air high above the earth's surface which has the ability to absorb, reflect, or divert various types of signals.

Line of sight: Electromagnetic signals travel straight from the transmitter to the receiver. Signals travelling by line of sight are relatively short-ranged, and are blocked by hills and other obstacles.

Low frequency (LF): LF is the band of frequencies from 30 to 300 KHz. The LF radio band has a relatively short transmission range (560-1,050 miles). A major disadvantage of LF radio signals is that they can only penetrate a few centimeters below water. LF communications are best-suited for two-way communication in a nuclear attack between bombers or submarines and their bases.

Medium Frequency (MF): LF is the band of frequencies from 300 KHz to 3 MHz.MF signals combine short range and relatively low band width, making them largely useless for military applications. Most commercial AM radio stations use the MF band due to its low military use.

Microwaves: Electromagnetic waves that are shorter than about 1 meter in wavelength.

Naval Communication Center: An activity established by the Secretary of the Navy, including all communications facilities and ancillary equipment required to provide essential interarea communication services for a specific area.

Naval Radio Station (NRS): An activity of the Naval Communication System that performs radio transmitting, radio receiving, and/or radio link relay functions. A type designating letter (T), (R), or (L) is added to indicate the functions performed.

Phased-array radar: Phased-array radars do not utilize conventional, mechanically scanned antennas but, instead, consist of hundreds or thousands of small emitters which are controlled, or "phased", by computer to generate electronically scanned beams. The main advantage of a phased-array system is that it can simultaneously track several targets, steer several missiles, and search for other targets or aircraft. This capability is called TRACK-WHILE-SCAN.

Pulse-doppler radar: This relatively new system combines both pulse and continuous wave (CW) techniques. Pulse-doppler radars are well-suited for use on aircraft and guided missiles.

Pulse type radar: Represents the earliest form of radar. In this system, the oscillator is switched on and off at a very high rate to generate short bursts of energy. These bursts are timed from transmission to return to calculate target range. The antenna for this system typically consists of a rotating mechanism that scans the horizon.

Radar: **R**adar **D**etection **a**nd **R**anging Apparatus. Based on the principle that ultra high-frequency radio waves travel at a definite speed and are reflected from objects they encounter. Waves are radiated as beams by directional antenna array that can be swept through space at all angles; the reflected wave is picked up by ultra high-frequency receiver. The elapsed time between transmission and reception of wave pulse is measured electronically to calculate the distance or range to a reflected object.

Radio communications: Term used to describe teletypewriter, voice, telegraphic, and facsimile communications.

Receiving antenna: Antenna used for reception of radio signals. Serves to convert arriving electromagnetic waves into corresponding modulated radio-frequency currents that flow through antenna circuit.

Receiving station: Station used for reception of radio signals or messages.

Skywave path: Radio signals are bounced back and forth between the earth's surface and the ionosphere

Superhigh frequency: SHF is the band of frequencies from 3 to 30 GHz. Signals, or microwave transmissions, travel by *line of sight*. These frequencies can be focused by a small dish antenna and directed into a narrow beam. The main advantage is that such a narrow transmission path is difficult to detect.

Telecommunications: Refers to communications over long distances and includes any transmission, emission, or reception of signals. Intelligence produced by visual means, wire, radio, or other electromagnetic systems also are included.

Transmitting station: A transmitting station is responsible for sending radio signals or messages. Typically, the transmitting station is located a distance from the communication center of a naval communication station. A type designating letter (T) is added to the installation name to indicate its function.

Tropospheric scatter path: Signals are bounced off the earth's troposphere, which lies only a few kilometers above ground.

Ultrahigh frequency (UHF): UHF is the band of frequencies from 300 MHz to 3 GHz. UHF signals share similar advantages and disadvantages of VHF communications. Communications with the UHF region can be achieved via a relay satellite.

Very high frequency (VHF): VHF is the band of frequencies from 30 to 300 MHz. VHF band has a range of 25 to 30 miles, and is capable of transmitting a large amount of data using a small antenna. VHF signals are achieved by *line of sight* propagation, where signals travel along a straight path from the transmitter to the receiver. As a result, interference from mountains and other obstacles degrades the VHF signals. VHF communications are widely used for combat radio networks that link ground units.

Very low frequency (VLF): VLF is the band of frequencies from 3 to 30 KHz. VLF signals have the ability of penetrating a few meters through the water. VLF bands can transmit data at a faster rate and rely on a relatively shorter transmission antenna than ELF signals. VLF systems are used primarily for one-way transmissions to submarines and ships.

Waveguide path: Signals are channelled between outer space and the earth's surface by the earth's ionosphere.

KEY TO ABBREVIATIONS

AT&T:	American Telephone & Telegraph
BMEWS:	Ballistic Missile Early Warning System
CCL:	Communications Control Link
CDAA:	Circularly Disposed Antenna Array
CIA:	Central Intelligence Agency
CIG:	Central Intelligence Group
CNO:	Chief of Naval Operations
COMMCEN:	Communication Center
COMINT:	Communications Intelligence
COMSEC:	Communications Security
COMSTA:	Communications Station
CW:	Continuous Wave
DCA:	Defense Communications Agency
DEW:	Distant Early Warning
D/F:	Direction Finder
DIA:	Defense Intelligence Agency
DoD:	Department Of Defense
ELF:	Extremely Low Frequency
ELINT:	Electronic Intelligence
ELSEC:	Electronics Security
EORSAT:	Electronic Intelligence Ocean Reconnaissance Satellite
ERDA:	Energy Research and Development Administration
ESM:	Electronic Signal Monitoring
EW:	Electronic Warfare
FBI:	Federal Bureau of Investigation
FCC:	Federal Communications Commission
FLTSATCOM:	Fleet Satellite Communications System
HF:	High Frequency
HF/DF:	High Frequency Direction Finding
ICBM:	Intercontinental Ballistic Missile
INR:	Bureau of Intelligence and Research
KC:	Kilocycle
KHz:	Kilohertz
KW:	Kilowatt
LANT COC:	Atlantic Communications Security Operations Center
LF:	Low Frequency
LOFTI:	Low Frequency Trans-Ionospheric Satellite
MC:	Megacycle
MHz:	Megahertz
MF:	Medium Frequency
MI:	Military Intelligence
MIT:	Massachusetts Institute of Technology
NAS:	Naval Air Station
NASA:	National Aeronautical Space Administration
NATO:	North Atlantic Treaty Organization
NAVFACENGCOM:	Naval Facilities Engineering Command
NAVCOMMSTA:	Naval Communication Station
NAVCOMMU:	Naval Communication Units

NAVRADSTA:	Naval Radio Station
NAVSECGRU:	Naval Security Group
NLFTF:	Naval Low Frequency Transmitter Facility
NORAD:	North American Air Defense Command
NRL:	Naval Research Laboratory
NRO:	National Reconnaissance Office
NRTF:	Naval Radio Transmitter Facility
NSA:	National Security Agency
NSGA:	Naval Security Group Activity
OCC:	Operational Control Center
OSRD:	Office of Scientific Research and Development
OSS:	Office of Strategic Services
OTH:	Over-the-Horizon
OTH-B:	Over-the-Horizon-Backscatter
QVI:	Quasi-Vertical Incident
RAD LAB:	Radiation Laboratory
RCA:	Radio Corporation of America
R&D:	Research and Development
ROTHR:	Relocatable-Over-the-Horizon Radar
RRF:	Radio Receiver Facility
RORSAT:	Radar Ocean Reconnaissance Satellite
SATCOM:	Satellite Communications
SCORE:	Signal Communication by Orbiting Relay Equipment
SIGINT:	Signals Intelligence
SPASUR:	Space Surveillance
SPECOM:	Special Communications
UHF:	Ultrahigh Frequency
USAF:	United States Air Force
USCG:	U.S. Coast Guard
USCIB:	United States Communications Intelligence Board
VHF:	Very High Frequency
VLF:	Very Low Frequency

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APPENDIX E

RESUMES OF KEY PROJECT PERSONNEL

KATHRYN M. KURANDA, M. ARCH. HIST.

VICE PRESIDENT - ARCHITECTURAL SERVICES, MID-ATLANTIC REGIONAL OFFICE

Ms. Kathryn M. Kuranda, M. Arch. Hist., Vice-President - Architectural Services, directs the architectural history and history programs of R. Christopher Goodwin & Associates, Inc. A graduate of Dickinson College and of the University of Virginia, Ms. Kuranda's professional qualifications exceed those established by the Secretary of the Interior in the field of architectural history. Ms. Kuranda possesses particular expertise in nineteenth and twentieth century vernacular architecture. She also is a court-qualified architectural historian.

Prior to joining Goodwin & Associates, Inc., Ms. Kuranda served as the architectural historian with the Nevada State Historic Preservation Office where she coordinated the state's program for built resources including: Survey and Inventory Activities; the Historic Preservation Tax Program; Review and Compliance; Public Education; and, Technical Assistance.

Since joining Goodwin & Associates, Inc., Ms. Kuranda has directed over 50 identification, evaluation, planning, and management projects for built resources. Ms. Kuranda directed the development of historic contexts for the Army Materiel Command's World War II Facilities; for Resources Associated with the Navy's Guided Missile Program, 1946-1989; and for Department of Defense Installations, 1790-1940. More recently, Ms. Kuranda directed the development of additional Nationwide Contexts for the U.S. Navy's Cold War Missile programs and the Navy's long-range communication systems. HABS/HAER recordation projects include eight industrial complexes on the site of Oriole Park at Camden Yards, Baltimore; three buildings on the site of the Maryland Library for the Blind and Physically Handicapped, Baltimore; and the Canal Street Car Barns, New Orleans. Ms. Kuranda has been responsible for the successful execution of numerous HABS/HAER projects. These include residential, commercial and industrial sites in the Mid-Atlantic, Northeastern, Western, and Southern states. She has designed and implemented evaluation and impact studies for the Montgomery County Resource Recovery Facility at Dickerson, Maryland, and for historic properties in the vicinity of Baltimore Gas & Electric Company pipeline corridors in Maryland. Currently, Ms. Kuranda is overseeing the preparation of the Pennsylvania State Museum's Geographic Information System (GIS) for archeological and historical resources for the central (Susquehanna Valley) quadrant.

BROOKE V. BEST, M.S.

PROJECT MANAGER

Ms. Brooke V Best, M.S., Architectural Historian, received a Bachelor of Science degree in environmental studies at the University of Vermont, with an emphasis on American architectural history and historic preservation. After graduating, she studied abroad in England and conducted architectural survey and research work for the Survey of London. In 1991, she received a Master of Science degree in Historic Preservation from the University of Pennsylvania. She also attended a conservation program sponsored by the International Center for Conservation of Rome (ICCROM) in Italy.

Ms. Best previously worked for a number of private architectural firms, where she gained experience in CAD drafting and research. After graduating from the University of Pennsylvania, she worked for the New Jersey Historic Preservation Bond Program, which awarded over $3 million in grants for preservation projects throughout the state. The following year, she served as the field supervisor for the $1 million exterior restoration of the ca. 1765 Morris-Jumel Mansion in New York City.

Since joining R. Christopher Goodwin & Associates, Inc., Ms. Best has prepared a conservation study for historic brick buildings at Aberdeen Proving Ground and completed HABS documentation for two nineteenth century buildings at Loyola University in New Orleans. Ms. Best has been involved in a number of research projects for the Naval Surface Warfare Center (NSWC), Dahlgren Division. These have included a Section 106 report, a cultural resources evaluation of the industrial and weapons testing area, and preparation of a National Register historic district nomination for the officer's housing area. Ms. Best also has been involved in a Legacy Resource Management Program demonstration project to develop a national thematic context for Cold War Navy guided missiles. Ms. Best conducted architectural investigations for two Naval Security Group Activity (NSGA) installations at Sabana Seca, Puerto Rico, and Northwest, Cheasapeake, Virginia. A thematic context for Navy ground-based communications systems is being developed in conjuntion with these architectural investigations. More recently, she has been working on the preparation of a maintenance plan for the historic buildings that comprise the Langley Field HIstoric District at Langley Air Force Base (AFB) in Hampton, Virginia.

KATHERINE GRANDINE, M.A.

PROJECT MANAGER

Ms. Katherine E. Grandine, M.A., Project Manager and Historian, received a Master of Arts degree in American Civilization with Emphasis on Historic Preservation in 1983 from the George Washington University, Washington, D.C. She has been professionally active in the field of historic preservation since 1981. Her project experience includes historic research, architectural surveys in Washington, D.C., Maryland, and Virginia, Historic American Buildings Survey documentation, National Register of Historic Places nominations, local landmark and historic district nominations, and survey of historically significant family housing for the Department of Defense. She has particular expertise in data management for historic properties including the Integrated Preservation Software (IPS) developed by the National Park Service.

Since joining Goodwin & Associates, Inc., Ms. Grandine has served as an historic preservation specialist in the development of the National Historic Context for DoD Installations from 1790 to 1940 and support and utility structures from 1917 to 1946 and performed reconnaissance-level and intensive-level architectural surveys at Aberdeen Proving Ground, Maryland; Charleston Naval Base, South Carolina; Fort Knox, Kentucky; Carlisle Barracks, Pennsylvania; FISC, Cheatham Annex, Virginia; Naval Weapons Station Yorktown, Virginia; and, Naval Base Norfolk, Virginia. She has conducted literature searches for Phase I surveys, including for the C & D Canal project in Maryland and Delaware, architectural surveys in Virginia, including the Potomac Palisades area in Arlington, and archival research for Phase II and Phase III archeological studies, including archeological data recovery at Site 44CS187 at NSGA Northwest. She has extensive experience in researching in local primary documents such as land records, deeds, and wills to support archeological projects. She has managed architectural survey and evaluation projects, written National Register nominations for individual properties and historic districts, co-authored a cultural resource management plan and numerous technical reports, and provided historic background research for a variety of cultural resources projects. She also has managed architectural survey databases and prepared exhibit panels and an informational brochure for Aberdeen Proving Ground, Maryland.