HISTORICAL ACCOUNT OF

RADAR TESTING AND DEVELOPMENT

FROM 1933 TO 1942

AT FORT HANCOCK, SANDY HOOK, NEW JERSEY

Prepared by Michael Eberhardt

NPS intern

For the National Park Service

Gateway National Recreation Area

Sandy Hook, New Jersey

21 May 2008

CONTENTS

HISTORICAL INTRODUCTION

Historic Fort Hancock, located on the northern end of the six mile long peninsula of Sandy Hook, New Jersey, contains a wealth of natural beauty as well as preserved history. Surrounded by the Atlantic Ocean to the east, New York Bay to the north and Sandy Hook Bay to the west, this area has been attracting visitors Seeking recreation and education for years. Open to the public as part of the Gateway National Recreation Area, Fort Hancock provides activities for its visitors, from relaxing on the beach, to fishing, bird watching, and cycling, as well as touring its historic landmarks. It is home to the America's oldest operating lighthouse, which has been a navigational guide for shipping in and out of the New York Harbor since it was built in 1764.[1] Fort Hancock also is home to many educational facilities, including the Marine Academy of Science and Technology High School, an oceanography lab for Brookdale Community College, and a research facility for National Oceanic and Atmospheric Administration.

Rich in military history, Fort Hancock was a strategic site used for coastal defense. Equipped with state of the art "disappearing guns" following the Civil War and with the "Nike Missile" during the Cold War, its coastal defense mission and contribution to the United States military was prominent for decades. Designated by the War Department as Fort Hancock in 1895 and deactivated in 1974, the fort was ultimately turned over to the National Park Service. [2] Today it offers its history to the public, from the gun emplacements along the coast, to "Officers Row" in the heart of Fort Hancock the area contains the remnants of the service it provided to America.

While many resources can be found which detail the entire coastal defense mission at Sandy Hook, this paper will focus on the testing, development, and production of Radar on Fort

Hancock during the years leading up to World War II. Tasked with the development and production of ship and aircraft detection devices, the Army Signal Corps laboratories at Fort Monmouth, provided the U.S. Army with early warning equipment known as radar. Evolving from sound detection and later heat detection of ships and planes, radar used radio waves to bounce off or echo back its emitted signal which established the location of incoming enemy ships or aircraft. During the inter-war years, the Signal Corps was instrumental in radar development and continued to display its importance well into World War II and beyond. Signal Corps work conducted at Fort Hancock played an integral role in the overall radar testing and development mission.

Early pioneers in radar development were either military or civilians assigned to the Signal Corps labs at Fort Monmouth. As the interest and demand for radar units increased within the Army, the staff and time spent on radar development at Fort Monmouth increased as well. Eventually, for security, space and logistical reasons, the entire testing, development, and production of radar at Fort Monmouth was moved to what is now known as "Fishing Beach" on Fort Hancock. There, the Signal Corps tested and developed, among other models, the SCR-268, SCR-270 and SCR-271 radar units, which were used as early warning systems during WWII.[3]

While the technical aspects of radar are scientific and detailed, the concept can be explained and understood with relative ease. In the late 19th century, a German physicist, Heinrich Hertz (1857-1894), discovered that radio waves could pass through certain materials, but would reflect off other materials. Croatian-Serb physicist Nikola Tesla (1856-1943) expanded on this concept when he proposed that a sending station could emit electromagnetic radio waves which would reflect off objects such as ships, determining their location based on time elapsed for the wave to return to the sending station.[4] Before long, scientists and military engineers realized the importance of radar as early warning detection of enemy sea and aircraft.

In the early 1900's, scientists were experimenting with radar throughout Europe. Eventually, the U.S. military developed radar for military application. In fact, the term radar, the acronym for Radio Detection and Ranging, was coined by the U.S. military early in WWII. Tested and developed at Fort Hancock, was first deployed in the Panama Canal Zone, as well as Hawaii and the Philippines. Eventually, radar units were positioned along the Pacific and Atlantic coasts of the United States and southern Canada. These units provided early warning in the event of incoming enemy attack. One radar unit in particular, positioned on the northern tip of Oahu, Hawaii, detected Japanese planes, from 132 miles out, as they approached Pearl Harbor on December 7, 1941.[5] Today radar is used in weather mapping, air traffic control, military defense, and law enforcement.

RADAR: FROM FORT MONMOUTH TO FORT HANCOCK

The development of radar for the U.S. Army was tasked to the Signal Corps based at Fort Monmouth. Its origin in military application during the early 1930's stemmed from a need to improve upon aircraft detection methods already in place. Initially, the military detected sea and aircraft by sound. Because the speed of sound was constant, an observer (listener) could establish direction from source origin, and distance from time elapsed sight to sound. As aircraft speed increased, this method became inaccurate. From sound detection came infrared detection. Again this scientific concept can be detailed however it simply means detecting objects by the electromagnetic radiation they emit.

From 1926-1930 infrared research and development was conducted by Ordnance Department of the Army. In 1931, aerial target detection by infrared methods was assigned to the Signal Corps, with research taking place at the Fort Monmouth laboratories.[6] After attempts at applying this concept into real world application, including the 1932 detection test done on a

blimp at Naval Air Station at Lakehurst, this method was proved "inadequate." As a result, Dr. Harold Zahl (1904-1973), introduced a thermal detector, which in 1933 was capable of detecting a lit cigarette at 100 feet away.[7] As the name implies, thermal detection detects objects such as sea and aircraft from the heat they generate and emit. From this point on, civilians such as Zahl worked together with the Army Signal Corps to produce heat and radio detection methods which led to the development of the first radar units for the U.S. Army.[8]

In July of 1933, with thermal detection research and development underway, the Signal Corps chose Fort Hancock, Sandy Hook, as its testing site. The availability of heavy commercial vessel traffic off the coast allowed for sufficient detecting and tracking by thermal units.[9] Testing conducted throughout the summer and fall of 1933 revealed accurate detection at "good range" with the thermal method. As a result, the War Department authorized this field of detection to be expanded to aerial targets and allocated $100,000 for its development.[10] Testing and development continued in and around Fort Monmouth to include Fort Hancock on the thermal detection method through the summer of 1935.

In July, 1935, final engineering tests of thermal detection equipment by the Signal Corps were conducted at the Twin Lights, Highlands, New Jersey. This location, which would be used extensively for testing as development continued towards an operating radar system, provided an elevated testing site at 225 feet above sea level. The Twin Lights test included the thermal detection equipment being used in conjunction with a high powered search light. Once thermal detection was acquired, the searchlight would spot and track the target. The U.S. Coast Guard Cutter Pontchartrain, designated as the target, was instructed to move about the ocean off the Atlantic coast of Sandy Hook.[11] The results of this test demonstrated an effective means of detection, but as development continued, some focus was shifted to detection by radio means in the form of pulse radar. This method, in development in Europe, was picked up by the U.S.

Army and assigned to the Signal Corps at Fort Monmouth for research.[12]

Pulse radar emitted radar (electromagnetic) waves which traveled at a constant rate (speed of light) and reflected back to the transmitter in the form of an echo. Early contributors to the pulse radar project were James Moore, John Hessel, John (J.J.) Slattery, and Dr. Zahl, who would all become officers in the Army Signal Corps. Pulse radar testing from August 1935 to January 1937, was conducted at both Fort Monmouth and Fort Hancock by the Signal Corps. An August 1935 test produced effective results over a long distance when the Signal Corps placed a transmitter on a roof top at Fort Monmouth and two receivers at Fort Hancock and Monmouth Beach, New Jersey. As research and development evolved, effective results were again produced during 1936 and early 1937 by detecting blimps and planes flying over the Fort Monmouth area.[13]

In May 1937, the Signal Corps demonstrated thermo-radio detection of aircraft for the top brass of the Army at Fort Monmouth. The equipment used was a combination of thermo detection and radio detection units supplemented with a searchlight for tracking. The observers present were Chief Signal Officer Major General James Allison, Chief of the Coast Artillery Corps General Brehon Somervell, Army Chief of Staff General Malin Craig, and Secretary of War Harry Woodring, as well as members of Congress. This demonstration yielded additional funds for radar development from the War Department budget, as well as orders transferring all testing and development activities to Fort Hancock.[14]

John Slattery, an active participant in the radar project from 1936 to 1942, later recalled the demonstration with some humor: “The system was demonstrated at Fort Monmouth on the eighth hole of the then existing golf course, much to the chagrin of all the officers, because they no longer had access to the eighth hole, and golf [for them] became a seventeen hole game.”[15] The Ft Monmouth Golf Course was not then located in a secure environment, but was bordered

by major thoroughfares and residential areas. This raised serious concern by the top brass in terms of mission security and secrecy. In fact, the nighttime demonstration and the searchlight used attracted the curious from the area to observe as well.

At the conclusion of the May 1937 demonstration, military brass took immediate action to secure this valuable asset. Secretary of War Woodring directed the transfer of all field activities in connection with aircraft detection work from Fort Monmouth to Fort Hancock "in order to maintain the requisite secrecy."[16] Chief of Staff Craig directed that a new section of scientists and researchers, named Radio Position Finding (RPF), be formed within the Signal Corps and assigned to the Fort Hancock radar testing and development. This section would be led by Captain Rex Corput (project officer) and Paul Watson (civilian chief). Fort Hancock was the natural choice for carrying out this mission. First, the entire Sandy Hook peninsula was a U.S. Army Coast Artillery Corps reservation, for which the work was being done. Next Sandy Hook had already been established as a testing site for earlier aircraft and ship detection testing. It was located close to the Fort Monmouth- based U.S. Army Signal Corps, and its physical land characteristics prevented unauthorized entry, as there was only one land based entrance.[17] Isolated on the peninsula, no one could see the testing and development project being done. With the location decided upon, section leadership selected, and the funds allocated, radar testing and development by the Army Signal Corps made official use of Fort Hancock as its base of operations.

RADAR AT FORT HANCOCK

The mission of the Signal Corps at Fort Hancock was to develop equipment for "detecting the location of aircraft and marine surface craft beyond visual range." [18] The area designated for radar development work was the area once known as South Beach, but known

today as Fishing Beach. In a letter to the Commanding Officer of Harbor Defenses, Sandy Hook Col. Alvin Voris described: The former Sandy Hook Proving Ground, east of Battery Kingman from the swamp in the middle of Sandy Hook eastward to the abandoned pole line approximately 100 feet shoreward from the beach, and extending from the most northerly abandoned railroad spur of the old magazine area for 200 yards north of the railroad spur and 200 yards to the south of the next abandoned railroad spur.[19]

By the fall of 1937, construction began by the Quartermaster Corps for Signal Corps laboratories on Fort Hancock. Initially two wooden structures were built. The first was a field house, a one story unit with a bungalow attic. Its size was 24 feet by 20 feet with a 14 foot by 10 foot wing and an 8foot covered porch across the front. This unit had six rooms that included, a shop room, guard room, boiler room, office, measuring instrument room and a bathroom. The second structure was a framed garage, 60 feet long by 24 feet wide with a slanted roof 18 feet high at the top and 10 feet high at the eaves. This building was three sided with an open front facing south. Both structures supported the first Fort Hancock radar developments and were eventually salvaged by the Army.[20] Eventually, the Commander of Harbor Defense provided more structures, and testing shelters to protect the radar units from the elements. The Works Progress Administration (WPA) provided the labor for these buildings as well as installed a water supply, fire protection, fencing and fence lighting.[21]

Development continued and the value of radar was demonstrated as German planes conducted bombing missions over England during World War II. Continued development led to expansion in radar personnel and testing space required. Additional resources in manpower and money were necessary as the need for early warning radar grew with America's approaching involvement in the war. By this time the project had been in progress for about three years. Reflecting its growth the Signal Corps requested and received more space. The expanded area of

operation at Fort Hancock is described in the Bearss Study as follows: The new northerly boundary to be a line parallel to and 1,000 feet north of Upton Road (present day Fishing Beach Road), the western boundary to be Hancock (Hartshorne Drive) Road, the southern boundary to be a line parallel to and 2,000 feet south of Upton Road, and the eastern boundary to be the ocean.[22]

The May 1937 decision to designate a Signal Corps Radio Position Finding section at Fort Hancock evolved into a radar development project that utilized sites in the surrounding area. Fort Hancock, Sandy Hook is located in northeastern Monmouth County. It is in close proximity to Sea Bright and Monmouth Beach to the south, the Highlands to the west, and Rumson to the southwest. All of these areas were used to support the mission at Fort Hancock, which was designated Field lab #3 in February 1942. Field Lab #3 included Fort Hancock and supporting areas, along with Field Lab #1 at Camp Coles, Little Silver, N.J., and Field Lab #2 in Eatontown, N.J., the Fort Monmouth Signal Corps mission was augmented.[23]

In 1935, Monmouth Beach was used for early pulse radar testing and the Twin Lights had also been used for various Signal Corps sea and aircraft detection testing. In March 1941, a two-story brick school house was obtained at and from Rumson for a fee of $1 per year to be used as an extension site of what would become Field lab #3. Official authority came from Fort Monmouth in March 1939, designating the use of the Twin Lights in support of the Fort Hancock RPF mission. The value of this site was recognized for its elevation (225 ft) from sea-level. At this height, compared to the sea level site at Fort Hancock, an evaluation of effects could be made regarding the effectiveness of aircraft detection equipment.[24]

As interest in and need for radar increased, evidenced by site expansion and what was occurring in Europe, the RPF departments and functions increased as well. Most were located at Fort Hancock and eventually moved in piecemeal to Camp Evans, which would become the final

location of Field lab # 3 in December, 1942. The addition of these sections to the RPF mission illustrates how the operation grew, as need for radar units increased. In August 1940, a drafting section was assigned to work out of Antenna Shelter #1 at Fort Hancock. This was a restricted area used to test and refine classified equipment pertaining to radar development. In the fall of 1941, a shop section was transferred from Fort Monmouth to Fort Hancock, where more room was made available to them. The shop section of the RPF unit was responsible for the fabrication of all models and experimental units, checking drawings for errors, and ensuring that the drawings conformed to safe shop practices. In January 1942, after America entered the war, a General Drafting section was established at Fort Hancock to assist with the demand for radar production. This section's work consisted of making drawings for general developments and alterations to radar units being tested and developed at Fort Hancock. Finally, in 1942, almost ten months prior to the move to Camp Evans, a Drafting Training School was established at Fort Hancock. Its initial enrollment had twelve students and two instructors. Enrollment increased and the school graduated one-hundred and twelve students who were assigned to various drafting sections at Camp Evans, after the three month course was complete.[25]

Following the May, 1937, demonstration and the established mission at Fort Hancock, the RPF section focused its resources on meeting the requirements established by the Army for the radio-thermal detection system, which was to be called the Set Complete Radio-268 (SCR-268).[26] While the May demonstration displayed its potential, the Army required the set to meet two specific characteristics before field use. Those specifications were:

> 1) Detect the presence of aircraft in a sector of approximately 120 degrees in azimuth, elevation 0 to 90 degrees. This sector represents the zone which the device must be able to cover by rapid sweeping in azimuth and elevation; the apparatus to be actuated by the heat radiation or radio waves set up by the airplane.
>
> 2) Register or indicate, in proper units of measure, the position of the located airplane, with respect to the detector or some other designated

> reference point; this indication of data [is] to be continuous so that the aircraft while in motion may be followed by a searchlight or observing instrument laid on such data.[27]

The May 1937 test at Fort Monmouth demonstrated the radar unit satisfied the first requirement, but work needed to be done to meet requirement #2. The demonstration revealed that directional data generated did not result in immediate searchlight placement on the aircraFort At the time the average error for azimuth data was about 70 mils, while the average error of elevation data was about 45 mils (a mil is a unit of measurement similar to degrees used to state direction, see note 23 for a detailed explanation). However this initial set did provide data upon operation and became the prototype for short range aircraft detection and tracking. Furthermore, the SCR-268 being developed at Fort Hancock was to become the "forerunner of long-range aircraft detection development," soon to be known as the SCR-270 and SCR-271. [28]

From the summer of 1937 to the summer of 1938, the RPF section at Fort Hancock developed and tested the SCR-268. Modifications were made which incorporated radio with thermal detection devices for aircraft detection, that resulted in a radar unit whose thermal locator could be set on a target using radio data.[29] Eventually, it was decided that the thermal detection portion of the SCR-268 could be eliminated altogether, and a unit utilizing detection by means of radio would produce sufficient results. This did not occur until further testing of the unit revealed this characteristic in early 1939.

In June 1938, the RPF section was under new leadership. Col. Roger Colton was named director and the new fiscal year budget, allocated additional funds to the project. Under the direction of Colton, the RPF section split the radar development project into four areas. Most of the resources focused on the original project, designated as SCR-268. Most of the remaining resources focused on an "offshoot" of the original model; this would become the SCR-270 and SCR-271. The next area of focus explored surface ship detection from early 1930 test models.

When fully developed, this would be designated as the SCR-296. Finally, the fourth area, designated miscellaneous, eventually produced a range-finder designated as the SCR-547.[30]

RPF work at Fort Hancock produced further modifications to the SCR-268 in 1939. During the early months, the unit was reconstructed to have three antennas, one to transmit a signal and two to receive. At this time, that the thermal portion of the unit was abandoned because testing revealed it was not as efficient as an all-radio model. By May 1939, a SCR-268 service test model was turned over to the Coast Artillery, for field testing. This model displayed a high degree of accuracy in detection but had some trouble maintaining tracking.[31] Tracking was essential for the Coast Artillery, however, because it was their duty to provide anti-aircraft fire in the event of an aerial attack. This meant that the enemy aircraft must be detected by the radar and that the radar unit must be capable of tracking the target in order to engage it with anti-aircraft fire.

As work continued on the SCR-268, SCR-270 and SCR-271, the RPF section of the Signal Corps at Fort Hancock contracted with Westinghouse and Western Electric. Both were electronics companies with significant resources in New Jersey which proved to be an asset for the radar testing and development project. Based on test models developed by the RPF section at Fort Hancock, Western Electric was contracted to produce the SCR-268 and Westinghouse was contracted to produce the SCR-270/271.

Because the testing site was on or near Sandy Hook, Westinghouse and Western Electric were assigned testing shelters on Sandy Hook, built for housing newly completed radar units for testing prior to shipping. Eight wooden test shelters were constructed for Western Electric in June 1941 for the production of 520 SCR-268s called for in the contract which was in addition to the 18 SCR-268s produced by the RPF section. This contract was an increase to earlier contracts initially calling for 212 sets then 418 sets. At the time, not enough draftsmen were available from

the RPF section to make the drawings to complete an order of this size. To compensate, Western Electric brought in its own engineers and draftsman to work alongside the RPF section at Fort Hancock.[32]

Similar activities were taking place with the development and testing of the SCR-270 and 271 models from 1938 through early 1942 prior to moving to Camp Evans. Both radar models had their "origin" in the development of the SCR-268, and were characterized as "the first U.S. Army radar" or the "original ancestor of all Army and Air Force radars."[33] The SCR-270 radar was a long-range, mobile unit comprised of an operating truck, power truck, and antenna trailer (see Appendix 11). This radar unit could locate and track aircraft at an altitude of 8,000 ft and a range of 85 miles though tests revealed its maximum range to be 138 miles.[34] This unit was also known as the "Pearl Harbor Radar," because it was the radar in operation on December 7, 1941. The SCR-271 was the fixed version of the SCR-270. Aggressive testing and development by the RPF section at Fort Hancock resulted in the SCR-271 being put into action in the Panama Canal Zone, at Fort Sherman Panama, in June 1940, seventeen months prior to the Pearl Harbor attack. At the time, the Canal Zone was considered to be the vulnerable point in America's coastal defense by the War Department. It was this region that received priority of early warning radar units. The SCR-271, developed at Fort Hancock and installed at Fort Sherman, became the first operating radar unit in the American defense system.[35]

The SCR-270 was born out of a need for long-range detection. While the May 1937 demonstration of the SCR-268 prototype, then being developed for the Coast Artillery, looked promising, this radar unit demonstrated the technological potential for other areas of the U.S. military. The Army Air Corps (1926-1941), the precursor to the U.S. Air Force, aware of the new radar being developed at Fort Hancock, requested an aircraft detection radar unit with a longer range. The Air Corps requested the unit be capable of detecting aircraft out to 120

miles.[36] Long-range detection was needed because once enemy aircraft was detected, its fighter squadrons would be launched to intercept the incoming enemy aircraft, which required more time than the SCR-268 could provide. That unit fit the need for coastal defense, giving a five minute warning, which was sufficient to lay anti-aircraft guns on the incoming enemy. Because the SCR-268 could not provide early warning, development began on the SCR-270 which would.

Testing of SCR-270 prototypes began in August 1938. Once again Twin Lights, in the Atlantic Highlands was used for the testing site. The radar unit demonstrated successful results and a "push" for field units for troops began.[37] When news of this initial testing reached the decision makers in Washington D.C., a directive was issued that work on long-range aircraft detection be given an "active development status," rather than the "research and development" classification it currently held. This directive was issued in the fall of 1938.[38] At the same time, in October 1938, Westinghouse, working with the RPF section on the SCR-270, developed a water-cooled vacuum tube, the critical component that emits a signal, for the radar unit. This tube made possible the connection of a high powered transmitter to a common antenna with a sensitive radar receiver. In other words this tube increased transmission power giving the SCR-270 its long-range capability.[39]

By January 1939, another contract was given to Westinghouse. This contract produced the necessary equipment to make the radar unit mobile. It called for a mobile antenna support for use with a mobile long-range detection station. As work progressed an antenna trailer was developed as well, designated the K-22-B, fully mobilizing the SCR-270.[40] Preliminary tests of the complete set had begun at Twin Lights in March. Daily testing of this unit began in June 1939 at Twin Lights. The SCR-270 detected and tracked aircraft flights departing from Mitchel Field, Uniondale, Long Island. Its maximum range of detection during this phase of testing was 150 miles, but it was determined that the radar was reliable at 80 miles.[41]

As mentioned, the SCR-270 was also known as the Pearl Harbor radar. Initial plans, however, called for early warning radar in Hawaii to be fixed SCR-271 units. In fact, delivery of the third, fourth and fifth units off the production line (the first and second SCR-271 units produced had been delivered to Panama) occurred on June 3, 1941. Installation was expected to be complete in 1942, once the designated sites were prepared. An issue arose in 1941 prior to installation which eventually dictated that the SCR-270 be used instead. One site chosen in Maui was a national park, under the responsibility of the Department of Interior. Use of this site required Department of Interior authorization, which was charged with the preservation of the area. The Department of Interior suggested other sites in Hawaii, to preserve the Maui site. The Army, unable to explain the importance of the still classified project, decided to use mobile units throughout Hawaii, which would diminish the impact that fixed units would have on the land. In doing so, sensitive material remained classified well into WWII.[42]

SCR-270 units arrived in Hawaii in August 1941. They were installed around the perimeter of Oahu and five units were in operation by September of that year. In October, a joint exercise by the Army and Navy stationed at Oahu, Hawaii, was conducted to test readiness of the early warning system. Carrier based naval aircraft simulated an attack during predawn hours with three Army SCR-270 radar units in operation for detection. The exercise went off smoothly. Naval aircraft were detected at 80 miles out. Immediately, notification went to interceptor aircraft on the ground. It took six minutes for interceptor aircraft to contact and engage the "enemy" aircraFort[43] This contact occurred 30 miles off the coast of Oahu, allowing for a comfortable buffer in the event of a real attack, reassuring those involved in the training exercise. Hindsight, however, provided critical criticism of this exercise. It worked flawlessly because it operated under flawless conditions.[44] All involved were aware of the desired outcome and all

were ready as the events unfolded. This exercise may have provided a false sense of security for Hawaii on December 7, 1941.

On the morning of December 7, 1941, Privates Joseph Lockard and George Elliot were on duty at Opana Point, the northern tip of Oahu, Hawaii, operating the SCR-270 radar unit. Their orders called for keeping the SCR-270 operational from 4:00am to 7:00am. The three hour restriction was designed to conserve resources. Replacement parts for these units had not yet arrived and so minimal use was ordered for conservation. Because predawn hours are considered most vulnerable for attack, this time period was designated for operation. At 7:00am, both soldiers prepared to take the unit out of action but were informed that their transportation from the radar site back to base would be late. Instead of shutting down, it was agreed the extra time would be used for training on the equipment. At 7:02am, an echo appeared on the instruments. The echo represented a large flight of aircraft detected 132 miles out and approaching at a speed of 3 miles per minute.

Initially both soldiers thought their equipment was malfunctioning. In their experience with this equipment they had never seen such prominent data being registered. Both checked the radar unit and determined it to be in good working order. At 7:20am, they called the information back to base at Fort Shafter. Being a Sunday morning, the information center at Fort Shafter only had two personnel on duty. One, Private Joseph McDonald, who took the call from Lockard and Elliot, was preparing to go off duty. The other, Lt. Kermit Tyler, would not have been present but for the suggestion of his Commanding Officer. Lt. Tyler was young and new to the operation and it was suggested that he put some time in at the information center that morning.

Elliot and Lockard continued to track and report the aircraft progress until the signal was impeded by the surrounding mountains at 7:39am. By this time, the Japanese were within 20 miles of the coastline. The data they received, processed, and sent to the information center was

never acted upon. Tyler had been informed earlier that a flight of friendly Army bombers were expected to fly in from the mainland that morning. This information was supplemented by the fact that Tyler had heard Hawaiian music played on the radio throughout the night. At the time this was a common practice to aid aircraft from the mainland to navigate towards Oahu. Tyler's response to Lockard and Elliot's information was "forget it." At 7:55am the Japanese attack on Pearl Harbor began.[45] This event overshadows the historical account of the functioning early warning radar on that morning.[46]

While the SCR-271 radar did not see action in Hawaii, it was the first long-range Army radar to be put into service. As mentioned earlier, the first and second units produced at Fort Hancock were shipped to Panama becoming the first radar unit in the American defense system. The First Signal Aircraft Warning Company was established for service in Panama in January 1940. One month later in February, the Second Signal Aircraft Warning Company was put into service as part of the Northeast Air Defense Command.[47] These companies would utilize the SCR-271s put into service for early warning defense. Testing on the developed unit began in 1940. In February and March the Twin Lights was again used by the Signal Corps RPF section. Demonstrating effective results in New Jersey, orders were placed by the Army for this set to be installed in Panama in May 1940. Delivery of SCR-271 equipment to Fort Sherman began a year later, in February 1941.[48]

Initial contracts with Westinghouse called for 21 SCR-271 units along with the SCR-270s that were already in production. This order, placed in late 1940, created a need for additional space so a building for assembly and testing was constructed in the area of Battery Arrowsmith at Fort Hancock (see Appendix 2,3, and 9). This addition to the RPF operation at Fort Hancock brought the total test shelters built for testing and producing radar units to nine. The first eight were built for General Electric and the RPF section for work on the SCR-268. Eventually, the

initial contract with Westinghouse increased. By June 1941, the contract called for 168 SCR-270s and 87 SCR-271s. [49]

While priority was given to production of units for Panama, production for the remainder of the American Defense System continued at Fort Hancock. The east and west coasts would be eventually supplied with either the SCR-270 or 271, as an early warning system in the event of an attack. Antenna height and clearance issues were raised however and modifications were requested as the first SCR-271s were set up in Panama. The 36 foot tower supporting the antenna structure required clearance of jungle foliage. Once the area was cleared, the fixed radar at Fort Sherman was "nakedly visible." Col. James Code at Fort Sherman requested modifications be made including elevating the towers to 100 feet in order to protrude the jungle canopy. This modification would require the RPF section to change the design. While modifications such as this were requested and instituted by the RPF section at Fort Hancock in the past, this time the request was denied. Priority was given to production so research and development would have to be put on hold for some time (For photo of the SCR-270 radar station at Fort Sherman, Panama, see Appendix 23).[50]

FROM FORT HANCOCK TO CAMP EVANS

Testing and development of Army radar by the RPF section of the Signal Corps officially had its base of operations at Fort Hancock from May 1937 through early 1942. Fort Hancock was used as a testing site as early as 1933, however, as the Signal Corps tested various thermal and infrared detectors. They remained on Fort Hancock continuing their work for sometime after the operation was officially moved to Camp Evans, in Wall Township, N.J. Various reasons have been offered to explain why the Signal Corps radar testing and development operation moved from Fort Hancock to Camp Evans in early 1942.

One reason was the need for additional space. As activities increased within the RPF section at Fort Hancock, interference between various departments and sections within the operation increased as well. In early 1942, it was decided that additional facilities requiring two types of construction needed to be implemented. First, buildings needed to be fireproof and second new buildings were required which provided additional space, were distanced from each other to prevent interference yet close enough for ease of travel for control, supply and administrative purposes.[51] Additional space unavailable at Fort Hancock was eventually found at Camp Evans.

Dr. Harold Zahl, who suggested the move requirement was based on space needed in his manuscript "History of Radar," also proposes another theory in Radar Spelled Backwards. Here Dr. Zahl recalls the vulnerability of Fort Hancock from German submarine attack. As Germany and Italy declared war on the United States on December 11, 1941, the main concern of the RPF section was not enemy aircraft as much as it was submarines. Zahl, an active participant within the RPF section at the time, recalls:

> Our lab was located in what might become one of the prime targets for submarines we knew could, and eventually would be lurking offshore. We were on a seven mile peninsula called Sandy Hook, on which many 12 inch coastal defense guns stood ready for defense but only against surface ships… A few well trained German commando type troops coming over via submarine conceivably might acquire temporary possession of this "island" and then figure out a way to point the 12 inch guns at nearby New York City. Thousands of rounds of ammunition were in storage and New York was less than twenty miles away; one needn't aim – just point would be enough.[52]

This theory was not unique. A German threat had been present since the May 1937 demonstration at Fort Monmouth. In fact high ranking observers at the demonstration believed the threat was real enough that the operation be moved onto the secure location of Fort Hancock to begin with. Another active RPF section participant at Fort Hancock, John Slattery, recalls a time when he and engineer John Hessel were preparing to run testing on a prototype of the SCR-

268 at the Twin Lights. The date was May 6, 1937 and the May demonstration had not yet occurred. The objective of this test recalls Slattery was to track the German Zeppelin Von Hindenburg as it approached the coastline en route to Naval Air Station Lakehurst. At around noon, prior to testing a storm approached and drenched the equipment rendering it inoperable. A few hours later at 7:25pm the Hindenburg caught fire and was destroyed as it made its mooring attempt in Lakehurst. This was a blessing in disguise for Slattery and Hessel. The following day the New York Times reported that German radio engineers, "aboard to listen for strange signals" were among the passengers on that flight. Slattery recalled that the RPF radar project's "secret" classification was almost compromised that day had it not been for the storm which postponed the testing.[53]

While not directly identifying the weather as a primary reason for the move to Camp Evans, Slattery did allude to this in an interview. He described the environment and its effects on the radar testing and development as being in the "proper position to take a terrific beating from any northeast storm that came there." [54] The shelters set up along the ocean front were designed to protect the equipment from the elements. The construction materials were mostly wood to decrease the adverse effects metal has on radar signals. The close proximity to the ocean, however, brought about unexpected problems. The northeast storms that occurred regularly coated the shelters with a thin layer of sea salt. This affected the radar operation as Slattery described, "We were trying to put radar rays through a conducting surface that in effect was just as good as if we put copper screening all over the building."[55] The reference to copper indicates the scattering effect that diminishes the radar's capability.

There were physical and environmental drawbacks to Fort Hancock. At sea level, Sandy Hook barely clears the ocean. Detection by way of radar operates more efficiently at higher elevations. To compensate for this drawback the RPF section utilized higher ground at the Twin

Lights repeatedly. In regards to the weather, Fort Hancock was exposed to the elements during all seasons. These, at times, ran extreme with a baking summer heat and an icy winter. The wind gusts were continuous but peaked during the September 1938 hurricane.[56] Fort Hancock was chosen for its proximity to Fort Monmouth, its security as a Coast Artillery reservation, and its isolation provided by its physical characteristics. Eventually, operational security, space and the environment all played a role in relocating the project to Camp Evans.

In January 1942, the drafting section moved from Fort Hancock to Camp Evans, immediately followed by the Machine and Carpenter shops. These sections moved into the Administrative building 1A while the Electric and Radio shops made their move in the same month to building 6 at Camp Evans. Operations continued at Fort Hancock but began to occur simultaneously at Camp Evans. This area had been home to Kings College but acquired by the Signal Corps for the purpose of relocating Field Lab #3.[57] It had been the previous site of Marconi's radio towers, used to send off shore wireless radio transmissions. Its proximity to Fort Monmouth was similar to that of Fort Hancock and the space available at this site could accommodate the ever growing Signal Corps radar testing and development project.

By June 1942, the General Drafting section at Fort Hancock had grown to 65 draftsmen in addition to its clerical staff. Its need for space was addressed as this section moved to the "H" building at Camp Evans on the 26th of that month. Following General Drafting section and one of the last to leave Fort Hancock was the Standard Control section. It moved from Fort Hancock to Camp Evans on November 17, 1942 and subsequently changed its name to the Technical Publications section. This new section consisted of 16 personnel most of which were students recently completing the Drafting Training school established at Fort Hancock in February of the same year.[58]

Camp Evans continued to support the Signal Corps mission throughout WWII and

beyond. Most officers and civilians assigned to the RPF section at Fort Hancock finished their careers at Camp Evans. Rich in history, the Signal Corps contributions at Camp Evans included Project Paperclip, which relocated German radar scientists and employed them for research with the U.S. Army, and Project Diana, the first successful attempt to bounce radio signals off the moon, opening the door to space exploration. Camp Evans was the home for satellite tracking of TIROS I and II, weather satellites that were the first of their kind in Space. Together with Signal Corps personnel at Deal Test Site, Ocean Township N.J. Camp Evans scientists tracked the Russian satellite Sputnik.[59] Today, located at Camp Evans is a science and history learning center called InfoAge. Among other things, it displays exhibits, documents, scientific instruments and military memorabilia. Directions and phone number can be accessed through the internet on its web site. Admission is free and open to the public however due to limited staffing; hours of operation are restricted to Sunday afternoons.

FORT HANCOCK TODAY

According to Tom Hoffman, Park Historian, Sandy Hook, the National Park Service policy is to allow nature to shape and impact the area without interference. Instead of preserving areas with man made structures or barriers, wind and water has and will continue to erode and reshape Sandy Hook. Some areas once used for testing and developing radar at Fort Hancock have already been covered by water or sand dunes that creep inland as time and wind demonstrate their effect. The SCR-268 test shelters, which once lined the shore at Fishing Beach, are now gone. Most of their concrete foundations are either eroded or buried. Two remain intact about 150 yards from the high tide line, apparently protected by small trees, brush and a sand dune just to the east. The SCR-270 shelter near Battery Kingman on the bay side has reached the same degree of ruin. Half of its foundation has collapsed and fallen into the bay. Its present

condition requires the park to restrict the area for safety reasons. These structures, once a vital component of radar development, are now gone. The historical account of Fort Hancock's contribution to America, its military and its people in regards to the role it played in developing the essential technology called radar, however, can still be preserved.

Many areas of Fort Hancock contain wayside exhibits detailing specific historical aspects of what remains in and around the area. Some of these include informational tables at the base of the lighthouse, and at the foot of the gun batteries. Each table provides a brief description of the role played in the defense and security of the region as well as the country. These exhibits are simple and effective informational tools. While the land and remnants of the radar testing shelters may not be preserved, a wayside exhibit, constructed in the area, would aid in preserving the historical account of radar development at Fort Hancock. Another useful tool would be to include locations and a brief history of radar testing and development inside one of the many brochures available to the public. To date, nothing in print, informs the public of the radar story. A one to two paragraph inclusion, with or without images, to existing pamphlets would change this. Better still, a three-fold pamphlet, similar to many found at Fort Hancock, would provide sufficient space to include a brief history.

The media; print, television and film, have all documented a portion of Fort Hancock's history. Despite the fact plenty of information is available on the Signal Corps' radar mission at Fort Hancock with the National Archives, military historical offices, Historical Electronics Museum in Maryland and private groups such as InfoAge, the full story of radar at Fort Hancock has yet to be told. Now is the perfect opportunity to preserve the story in detail. Personnel and financial resources available within the National Park Service, working together with the various groups listed above, could prepare and maintain an accurate account of this vital piece of our history. A printed document, kept on file could be up-loaded to the National Park Service

website, while a documentary film could be available for viewing at the Sandy Hook Visitor Center. In addition, historic landmark designators as well as wayside exhibits can be placed in the area where actual work of the radar development project was performed. Two positive aspects of this suggestion are first, low installation and maintenance cost, and second, low environmental impact.

Present day policy may very well lead to a lost opportunity. In the future, when educators, students, and the ever growing number of park visitors, come to get the complete story of Fort Hancock history, will they be fully informed of Fort Hancock's significant impact in the field of radar? Will their learning experience reach its potential? In order to answer yes, the historian, aided by all available resources, needs to preserve this history. Should Park policy be revised concerning sand replenishment at Fishing Beach, the historical account and remnants of radar testing and development needs to be stabilized, preserved, and memorialized. Radar was extremely vital to the military mission into and beyond WWII. Its evolution now impacts everyday military, law-enforcement, weather and air travel activities. Its origin of application can be traced back to the pioneers whose contributions to radar testing and development at Fort Hancock should not be forgotten.

NOTES

[1] National Park Service, U.S. Department of Interior, Gateway National Recreation Area, "Sandy Hook Lighthouse." http://www.nps.gov/archive/gate/shu/pdf_files/history_sh_lighthouse.pdf (accessed March 6, 2008).

[2] Secretary of War Daniel Lamont signed General Order 57 on 30 October 1895 which officially activated Fort Hancock. See, General Order 57 October 30, 1895, General Orders and Circulars, Adjutant Generals Office, 1895, War Department Washington D.C.; for deactivation date see, Thomas Hoffman, "The Defenses of Sandy Hook," http://www.nps.gov/archive/gate/shu/pdf_files/history_defenses_of_sandy_hook.pdf (accessed on March 10, 2008).

[3] While this source will be cited a number of times throughout this paper, for a complete account of Fort Monmouth Signal Corps' involvement in the testing and development of radar for the U.S. Army and U.S. Coast Artillery, see U.S. Department of Army, Draft Manuscript, Historical Report: Signal Corps Engineer Labs: 1930-1943, folders 1-4, courtesy of Command Historian, Fort Monmouth C-E LCMC Historical Office.

[4] Wallace Brand, Malcolm Watts and John Wagner, "Nikola Tesla: Forgotten American Scientist," http://www.ntesla.org/provide_p.13.html (accessed on 12 March 2008).

[5] National Park Service, Department of Interior, Opana Memorial Information Table and Plaque located Turtle Bay, Oahu, Hawaii, (visited and photographed on March 24, 2008); for photos of site where radar unit SCR-270 (developed and produced at Fort Hancock) detected Japanese planes 53 minutes prior to bombing Pearl Harbor on December 7, 1941 see Section VII: Maps and Photographs in this paper.

[6] U.S. Army, Engineering Test Manual for May 1937 Experimental Types of Detectors for Use Against Aircraft: Heat and Radio, prepared at Signal Corps Laboratories, Fort Monmouth New Jersey, May 17, 1937, p. A. Courtesy of Command Historian, Fort Monmouth C-E LCMC Historical Office.

[7] Harold Zahl, History of Radar (Draft Manuscript, April 13, 1954), p.9. Courtesy of Command Historian, Fort Monmouth C-E LCMC Historical Office. Dr. Zahl was one of many pioneers in the testing and development of radar for the U.S. Army. His participation in the project involved time spent with the Signal Corps at Fort Monmouth, Fort Hancock and Camp Evans, the final location of the Radio Position Finding (R.P.F.) section of the Signal Corps assigned as the test and development section for radar. Dr. Zahl has written extensively on radar development. For more see, Harold Zahl, Electrons Away, (New York: Vantage Press, 1968); Radar Spelled Backwards, (New York: Vantage Press, 1972).

[8] Zahl, History of Radar

[9] U.S. Army, Historical Report: Signal Corps

[10] U.S. Army, Engineering Test Manual for May 1937, p. A.

[11] U.S. Army, Historical Report: Signal Corps, p. 88.

[12] Ibid.

[13] Zahl, History of Radar, p. 17.

[14] Ibid, pp. 18-19.

[15] John Slattery, interviewed by Mark Slattery, Maui, Hawaii, June 3, 2001. Transcript in possession of author, courtesy of Command Historian, Fort Monmouth C-E LCMC Historical Office.

[16] U.S. Army, Historical Report: Signal Corps, p. 240.

[17] Dulany Terrett, United States Army in World War II, The Technical Services, The Signal Corps: The Emergency, (Washington D.C.: GPO, 1956), p.122.

[18] Edwin Bearss, Historic Resource Study: Fort Hancock 1895-1948, Denver Service Center, United States Department of Interior, Denver Colorado, p. 593.

[19] Ibid, Voris quoted in Bearss, cited in note 89 as Col. Voris to Commanding Officer, Harbor Defenses of Sandy Hook, July 6 1937, Defenses of Sandy Hook, Records Group 77, WNRC.

[20] Bearss, Historic Resource Study, p.464. Cited in note 101 as Completion Report on Erection of Field House and Garage Shed at Fort Hancock, New Jersey, May 17, 1938, Fort Hancock, 1922-1939, Records Group 77, WNRC.

[21] U.S. Army, Historical Report: Signal Corps, p. 35.

[22] Bearss, Historic Resource Study, p. 594. Cited in note 90 as Colton to Commanding General, II Corps Area, September 16, 1940, Defenses of Sandy Hook, Records Group 77, WNRC. Col. Roger Colton was in charge of the project.

[23] U.S. Army, Historical Report: Signal Corps, p. 38.

[24] Ibid, pp. 33, 35, 261.

[25] Ibid, pp. 379, 380, 382, 408.

[26] SCR-268 was also referred to as Signal Corps Radio-268, both Set Complete and Signal Corps were used interchangeably. The term radio was applied to the unit because the radar development project underway was a classified operation. For operational security the term radar would not be used in anything but secret documents.

[27] U.S. Army, Historical Report: Signal Corps, p. 251. An azimuth is a direction stated in degrees or mils where 0 degrees or mils on a compass is magnetic north and 0 degrees or mils on a map is grid north.

[28] Ibid, p. 251-252, 256. A mil is a unit of angular measurement used by, among others the U.S. military. There are 6,400 mils in a circle so 6,400 mils = 360 degrees. With this known data a conversion of mils to degrees or degrees to mils can easily be made. 70 mils = about 4 degrees, 45 mils = about 2.5 degrees. It is important to note that for every 1 degree in error at a distance of 1,000 meters will compound the error to 1 meter in actual distance. If I shoot a 16 degree azimuth at an object 1,000 meters away and the actual location is on a 15 degree azimuth, there will be a 1 meter difference in where I believe the object to be and where the object actually is. The target for the May 1937 demonstration was at a distance of 55,000 yards from the detection unit. Converted to meters this would be about 45,700 meters away. So a 4 degree error in azimuth at a distance of 45,000 meters yields an actual distance error of 180 meters or about the distance of two football fields.

[29] Ibid, p. 248.

[30] Terrett, The United States Army in WWII, p. 124.

[31] U.S. Army, Historical Report: Signal Corps, p. 257-258.

[32] Zahl, History of Radar, p. 24.

[33]For "first U.S. Army radar" see Terrett, The United States Army in WWII, p.46; For "original ancestor" see Arthur Vieweger and Albert White, "Development of Radar: SCR-270," http://www.monmouth.army.mil/historian/docdisp.php?fname=vieweger-scr-270.doc&dirname=Equipment+and+Systems%2FSCR+270 (accessed on January 31, 2008) p. 2.

[34] U.S. Army, Historical Report: Signal Corps, p. 261.

[35]Vieweger, "Development of Radar," p. 5.

[36] Terrett, The United States Army in WWII, p. 47.

[37] Vieweger, "Development of Radar," p. 3.

[38] U.S. Army, Historical Report: Signal Corps, p. 259.

[39] Vieweger, "Development of Radar," p. 3.

[40] U.S. Army, Historical Report: Signal Corps, pp.259-261.

[41] Terrett, The United States Army in WWII, p. 128. Mitchel Field, in use from 1917-1961, was located in Uniondale Long Island. This Army Air Corps base provided aircraft flights as targets for radar testing and development at Fort Hancock.

[42] Terrett, The United States Army in WWII, pp. 302-303.

[43] Terrett, The United States Army in WWII, p. 304.

[44] Ibid.

[45] Dulany Terrett, United States Army in World War II, The Technical Services, The Signal Corps: The Test, (Washington D.C.: GPO, 1956):pp. 3-5. This is Volume 2 in a 3 volume set. Volume 1 has been previously cited as "The Emergency" and volume 3 completes the set titled "The Outcome." For more on the account of the Fort Hancock produced SCR-270 radar unit detecting the Japanese aircraft on December 7, 1941 see, U.S. Army, Historical Report: Signal Corps; Vieweger, "Development of Radar"; Zahl, History of Radar; www.infoage.org; www.monmouth.army.mil.

[46] I visited the Opana Point area and the Pearl Harbor Memorial in March 2008 with the hope of accumulating more documentation, photos and perhaps personal accounts of the incident, specifically the role that the Fort Hancock developed SCR-270 radar played in the history of Hawaii. Most historical accounts I came across during the visit dealt primarily with the actual attack. Not surprisingly, this event dominates Hawaiian military history and overshadows anything available on the radar unit. Further frustrating my research I was denied access to Opana Point. Today it is restricted to authorized military personnel only. Its use I believe is for a communications project. At sea level, below Opana Point however is an informational memorial containing three plaques dedicating the site to the SCR-270 and its successful detection of the Japanese attack. This site is on the coast at the northern tip of Oahu Hawaii. The property is owned and operated by the Turtle Bay Hilton who allowed the Department of Interior to construct the memorial. Photos taken of Opana Point, a line of sight view along the azimuth detected by the SCR-270, and the Department of Interior Memorial at Turtle Bay are included in the maps and photos section.

[47] Vieweger, "Development of Radar," p. 5.

[48] Zahl, History of Radar, p. 27, 29.

[49] Ibid, p. 29.

[50] Terrett, The United States Army in WWII: The Test, p. 284.

[51] Zahl, History of Radar, p. 31. The fireproof requirement stemmed from a March 1941 accident. Antenna shelter #2 at Fort Hancock was destroyed by fire. This shelter housed all receiver development work of the RPF section, partly completed radar equipment as well as testing apparatus. Fortunately records and drawings had been moved from this shelter and stored elsewhere a few days prior to the fire. For more see U.S. Army, Historical Report: Signal Corps, p. 35.

[52] Harold Zahl, Radar Spelled Backwards, (New York: Vantage Press, 1972)

[53] Slattery, Oral Interview, June 2001.

[54] Ibid.

[55] Ibid.

[56] Terrett, The United States Army in WWII: The Emergency, p. 122.

[57] U.S. Army, Historical Report: Signal Corps, pp. 37, 379, 409.

[50] Ibid. pp. 380, 382.

[59] InfoAge web site, www.infoage.org

BIBLIOGRAPHY

I. PRIMARY SOURCES

A. Books

Zahl, Harold. Electrons Away: Tales of a Government Scientist. New York: Vantage Press, 1968.

____. Radar Spelled Backwards. New York: Vantage Press, 1972.

B. Draft Manuscript

Zahl, Harold. History of Radar. April, 1954. On file with the Command Historian, Ft. Monmouth, C-E LCMC Historical Office.

C. Oral Interviews

Jones, Julian. Interviewed by Tom Hanley. Sandy Hook, New Jersey, May 15, 2004. On file at Gateway National Recreation Area/Sandy Hook.

Jones, William. Interviewed by Prof. Robert Johnson. Framingham Massachusetts, December 2, 1993. Transcript in possession of author.

Kennedy, Peter. Interviewed by Michael Eberhardt. Lincroft, New Jersey, April 4, 2008. On file at Center for World War II Studies and Conflict Resolution, Brookdale Community College, Lincroft, New Jersey.

Kennedy, Peter. Interviewed by Tom Hanley. Sandy Hook, New Jersey, February 2, 2004. On file at Gateway National Recreation Area/Sandy Hook.

Marchetti, John. Interviewed by Fred Carl. Wall, New Jersey, January 9, 1999. On file file at www.infoage.org.

Siciliano, May. Interviewed by Tom Hanley. Sandy Hook, New Jersey, January 26, 2004. On file at Gateway National Recreation Area, Sandy Hook.

Slattery, John. Interviewed by Mark Slattery. Maui, Hawaii, June 3, 2001. Transcript in possession of author.

Smith, Philip. Interviewed by Frank Polkinghorn. New Brunswick, New Jersey, January 19, 1973. Transcript in possession of author.

D. Government Documents

U.S. Army. Engineering Test Manual For May 1937 Experimental Types of Detectors for Use Against Aircraft: Heat and Radio. Prepared by Signal Corps Laboratories, May, 1937. On file with the Command Historian, Ft. Monmouth, C-E LCMC Historical Office.

U.S. Army. Historical Report, Signal Corps Engineer Labs: 1930-1943. Prepared by Signal Corps Laboratories, no date available. On file with the Command Historian, Ft. Monmouth, C-E LCMC Historical Office.

E. Papers

Vieweger, Arthur, Albert White. “Development of Radar: SCR-270,” found at www.monmouth.army.mil accessed on January 31, 2008.

II. SECONDARY SOURCES

A. Books

Terrett, Dulany, George Thompson, Dixie Harris, and Pauline Oakes. U.S. Army in WWII, The Technical Services, The Signal Corps: The Emergency. Washington D.C.: Government Printing Office, 1956.

Terrett, Dulany, George Thompson, Dixie Harris, and Pauline Oakes. U.S. Army in WWII, The Technical Services, The Signal Corps: The Test. Washington D.C.: Government Printing Office, 1956.

Terrett, Dulany, George Thompson, Dixie Harris, and Pauline Oakes. U.S. Army in WWII, The Technical Services, The Signal Corps: The Outcome. Washington D.C.: Government Printing Office, 1956.

B. Government Documents

Bearss, Edwin. Historic Research Study, Fort Hancock:1895-1948. Prepared at Denver Service Center, Historic Preservation Division, U.S. Department of Interior, Denver Colorado, May 1981. Gateway National Recreation Area Sandy Hook.

C. Websites

Brand, Wallace, Malcolm Watts, and John Wagner. "Nikola Tesla: Forgotten American Scientist." No date. http://www.ntesla.org/provide_p.13.html (Accessed on March 12, 2008).

Carl, Fred. No date. www.infoage.org (Accessed on March 4, 2008).

Department of Interior, National Park Service, Gateway National Recreation Area, "Sandy Hook Lighthouse." N.A. http://www.nps.gov/historyculture/upload/sh_lighthouse.pdf (Accessed March 6, 2008).

Department of Interior, National Park Service, Gateway National Recreation Area, "The Defenses of Sandy Hook." Hoffman, Thomas. http://www.nps.gov/gate/historyculture/upload/defenses_of_sandy_hook.pdf (Accessed March 10, 2008).

Helgeson, Donald. "SCR-270 Historical Notes." www.radomes.org/museum/equip/SCR-270.html (Accessed on January 31, 2008).

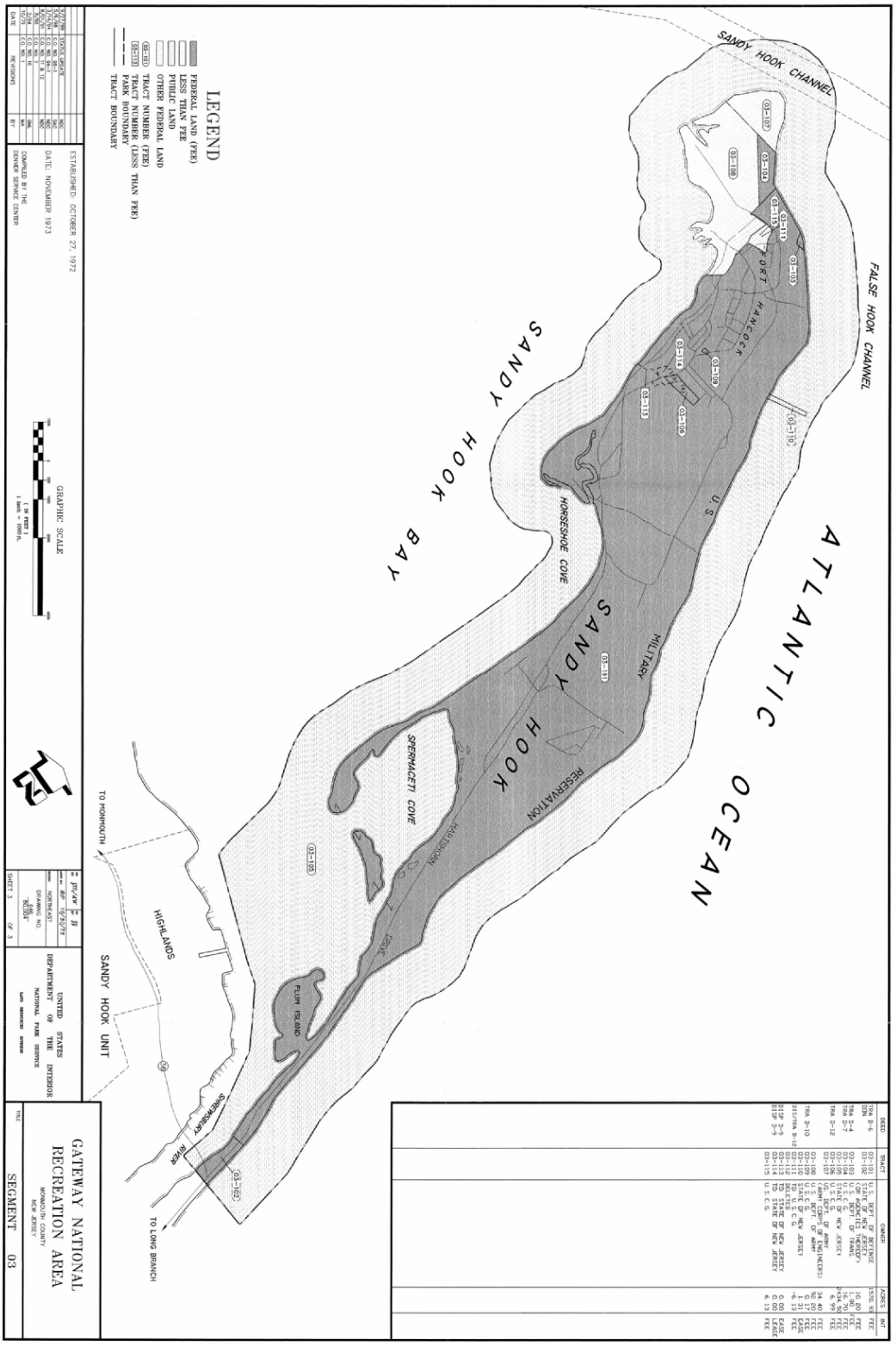
United States Army, Fort Monmouth. www.monmouth.army.mil/historian. (Accessed on January 31, 2008).

APPENDIX: MAPS AND PHOTOGRAPHS

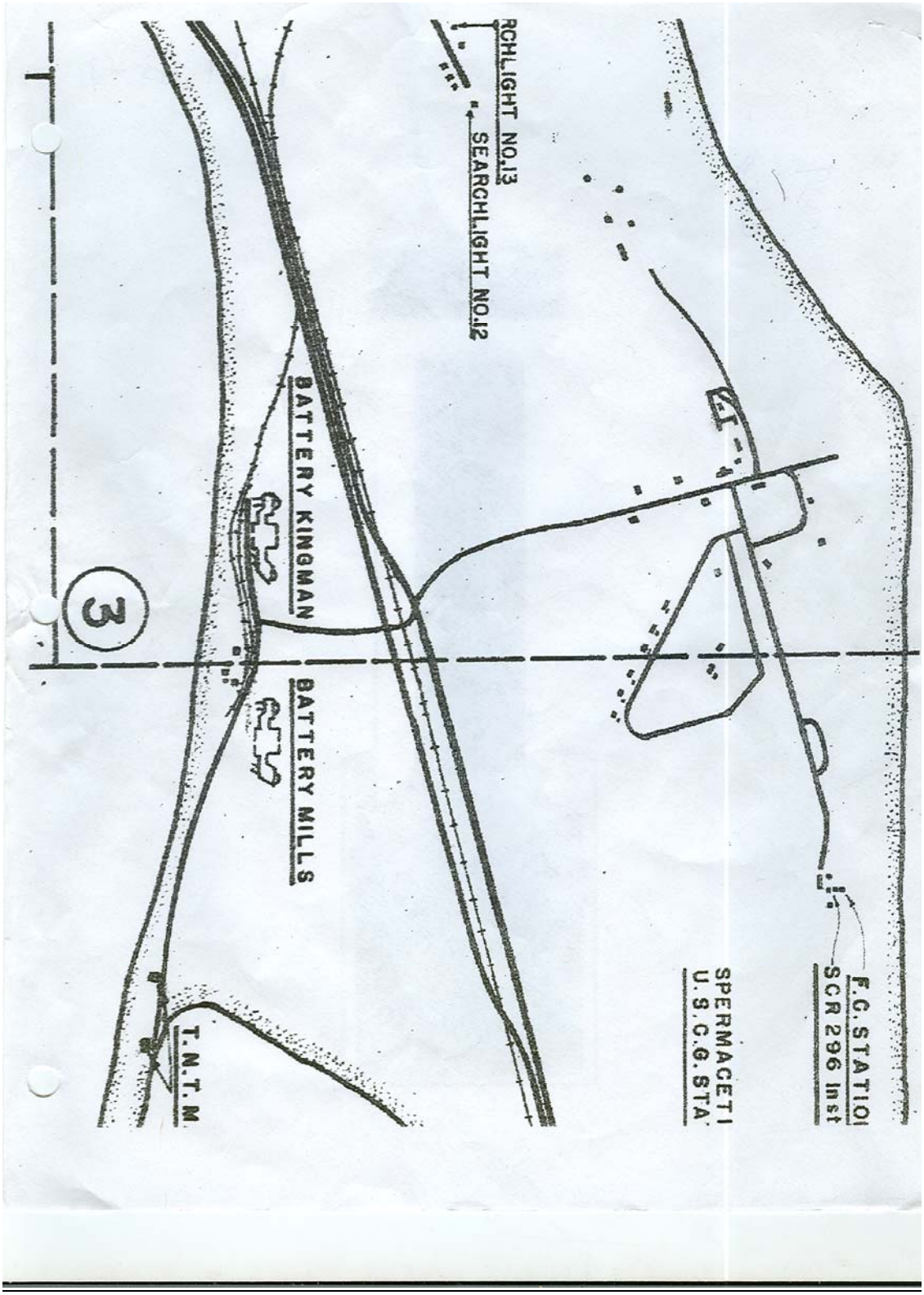
1. "Gateway National Recreation Area", United States Department of the Interior: November, 1973. Courtesy of Gateway NRA/NPS Museum Collection
2. Radar testing and development locations at Ft. Hancock. Right side of image is the eastern coastline section of Fishing (South) Beach. Courtesy of Gateway NRA/NPS Museum Collection (Sections 3 and 4 from Catalog # 1009).
3. "Radar development area at Ft. Hancock" Picture of SCR-268 Antenna Shelters with Sandy Hook terrain in the foreground and the Atlantic Ocean in the background. Courtesy of Electronics Command Museum, Fort Monmouth. Copy at Gateway NRA/NPS Museum Collection (Catalog # 8233).
4. "SCR-268 Radar Antenna Shelters at Ft. Hancock". Taken October 29, 1941. Courtesy of Electronics Command Museum, Fort Monmouth. Copy at Gateway NRA/NPS Museum Collection (Catalog # 8235).
5. Concrete foundation of SCR-268 Radar Shelter as it stands today. Photo taken by author April 24, 2008
6. Concrete foundation of SCR-268 Radar Shelter as it stands today additional view. Photo taken by author April 24, 2008
7. "SCR-270 Test Shelter at Ft. Hancock" used for the assembly and testing of the SCR-270 and SCR-271 Radar units. Photo taken November 3rd, 1941. Courtesy of Electronics Command Museum, Fort Monmouth. Copy at Gateway NRA/NPS Museum Collection (Catalog # 8237).
8. Remaining concrete foundation as it stands today at Battery Arrowsmith, Ft. Hancock. Photo taken by author April 24, 2008.
9. Remaining concrete foundation as it stands today at Battery Arrowsmith, Ft. Hancock additional view. Photo taken by author April 24, 2008.
10. "SCR-268 with Shelter in the background at Ft. Hancock" Courtesy of Electronics Command Museum, Ft. Monmouth (item # 2340).
11. SCR-268 Radar in action at Ft. Hancock. Courtesy of Electronics Command Museum, Ft. Monmouth (item # 2821).

12. “SCR-268 Searchlight” used to illuminate and track aircraft in flight after detected by the Radar unit. Courtesy of Electronics Command Museum, Ft. Monmouth (item # 1300).
13. “Early Thermolocator with Searchlight at Twin Lights” used as a surface ship locator. Photo taken in 1935. Courtesy of Electronics Command Museum, Ft. Monmouth (item # 1344).
14. SCR-268 Sketch courtesy of Pete Kennedy, Sea Girt New Jersey
15. SCR-270 testing at Ft. Hancock. Courtesy of Electronics Command Museum, Ft. Monmouth (item # 2474).
16. “Components of the SCR-270 (Mobile) Radar Unit” Courtesy of Electronics Command Museum, Ft. Monmouth (item #0116).
17. “SCR-270 at Oahu Hawaii, also known as Pearl Harbor Radar” Courtesy of Electronics Command Museum, Ft. Monmouth (item # 2559).
18. “Entrance Sign for Opana Point” Photo taken by author March 2008.
19. “Opana Point, Oahu, Hawaii” Taken by author March 2008 from low ground approximately ¼ mile away. This shot is of the eastern face, left side of photo is north, beyond is Pacific Ocean.
20. “Opana Radar Site Plaque #1” located on the shoreline below Opana Point on the grounds of the Turtle Bay Hilton. Photo taken by author March 2008.
21. “Opana Radar Site Plaque #2” located on the shoreline below Opana Point on the grounds of the Turtle Bay Hilton. Photo taken by author March 2008.
22. “Opana Radar Site Informational Memorial” located on the shoreline below Opana Point on the grounds of the Turtle Bay Hilton. Photo taken by author March 2008. This photo depicts the azimuth and time plotted by Privates Elliot and Lockard on December 7, 1941.
23. “SCR-271 at Ft. Sherman Panama” Photo taken from www.ibiblio.org/.../img/USA-WH-Guard-p313.jpg.

Appendix 1


SANDY HOOK CHANNEL
FALSE HOOK CHANNEL
ATLANTIC OCEAN
SANDY HOOK BAY
FORT HANCOCK
HORSESHOE COVE
SANDY HOOK
RESERVATION
SPERMACETI COVE
HIGHLANDS
SANDY HOOK UNIT
TO HOWMOUTH
TO LONG BRANCH
LEGEND
FEDERAL LAND (FEE)
LESS THAN FEE
PUBLIC LAND
OTHER FEDERAL LAND
(05-107) TRACT NUMBER (FEE)
(05-110) TRACT NUMBER (LESS THAN FEE)
PARK BOUNDARY
TRACT BOUNDARY
GRAPHIC SCALE
ESTABLISHED: OCTOBER 27, 1972
DATE: NOVEMBER 1973
COMPILED BY THE DENVER SERVICE CENTER
GATEWAY NATIONAL RECREATION AREA
MONMOUTH COUNTY
NEW JERSEY
SEGMENT 03
UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
LAND RESOURCES DIVISION
DRAWING NO. 80,004
SHEET 3 OF 3

Appendix 2


RCHLIGHT NO.13
SEARCHLIGHT NO.12
BATTERY KINGMAN
BATTERY MILLS
T.N.T.M
SPERMACETI
U.S.C.G.STA
F.C.STATIO
SCR 296 inst
3

Appendix 3

Appendix 4

Photo SCGDL No. 469-3, 10-29-41.

Figure 1.

RADAR ANTENNA SHELTERS

Examples of externally-buttressed wooden antenna shelters whose non-metallic construction permitted adjustment and testing of Radio Set SCR-268 without exposure to the weather. The row of shelters shown here was built by Western Electric on the Signal Corps restricted reservation at Fort Hancock. The foreground illustrates terrain of Sandy Hook.

(See Chapter I, C, page 8.)

Appendix 5

Appendix 6

Appendix 7

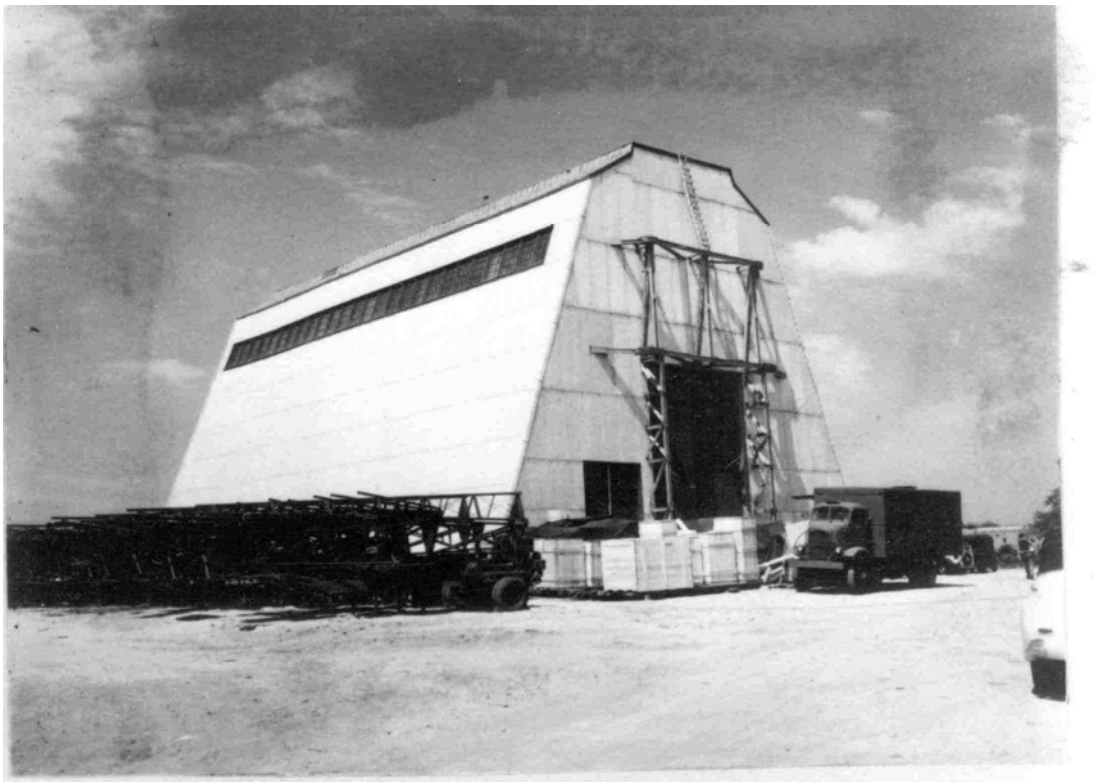


Photo SCGDL No. 471-S, 11-3-41.

Figure 4.

SCR-270 TEST SHELTER

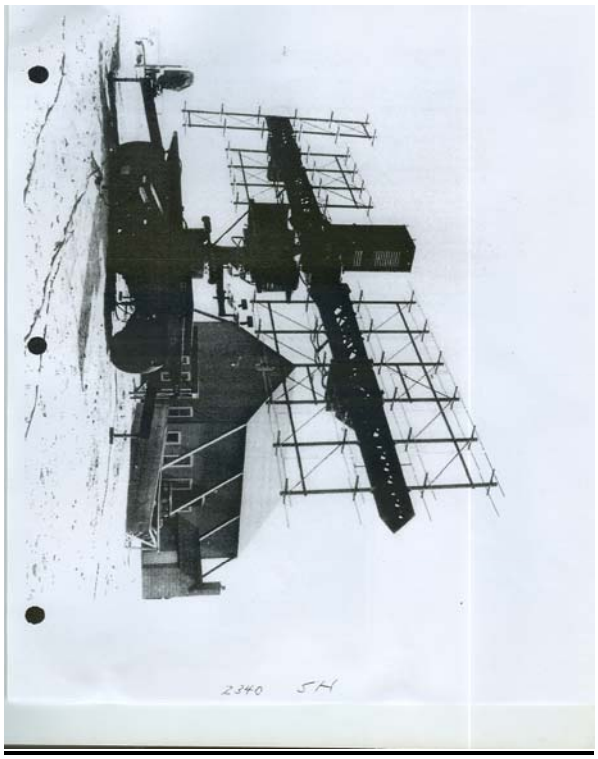
Antenna test shelter constructed by Westinghouse at the Signal Corps Field Laboratory, Fort Hancock, for assembly and test of Radio Set SCR-270. A row of trailer antenna mounts may be seen outside the building.

(See Chapter I, C, pp. 12-13.)

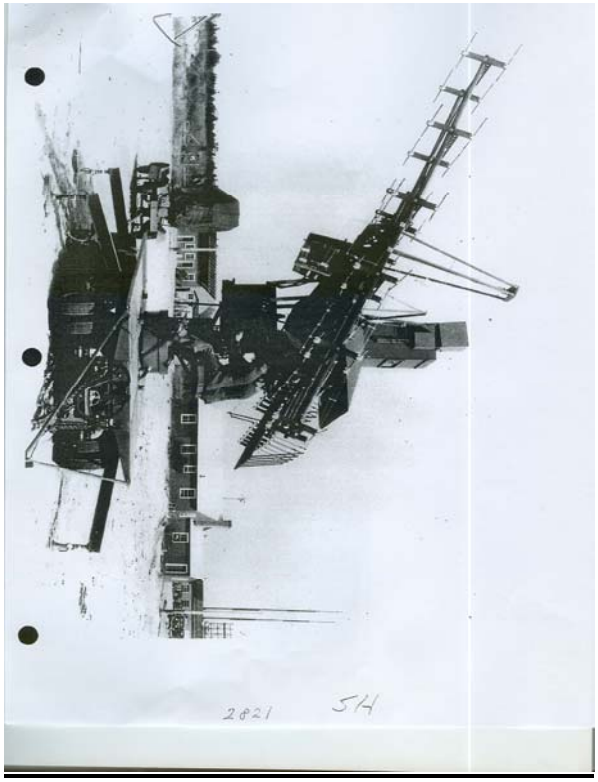
Appendix 8

Appendix 9

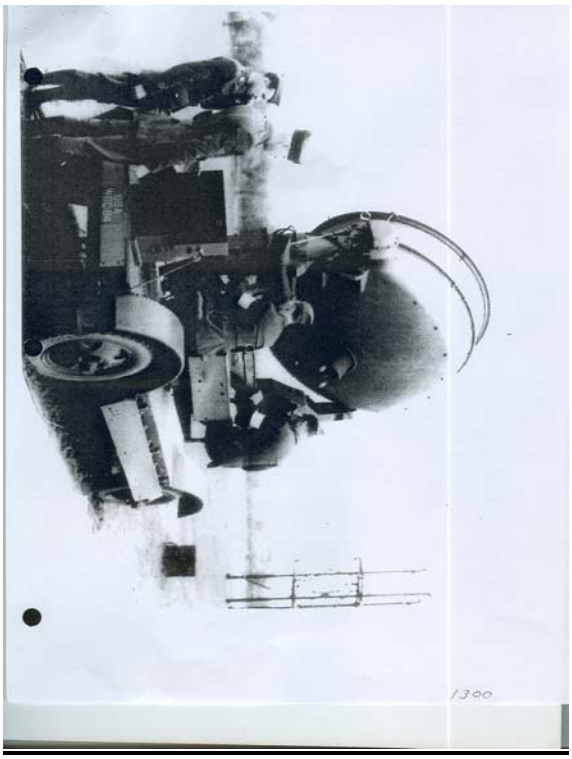
Appendix 10



Appendix 11

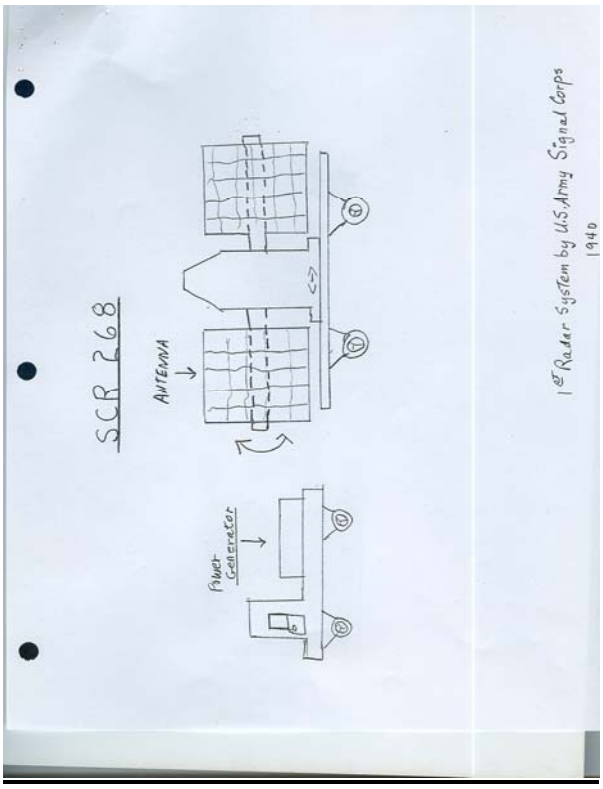


Appendix 12



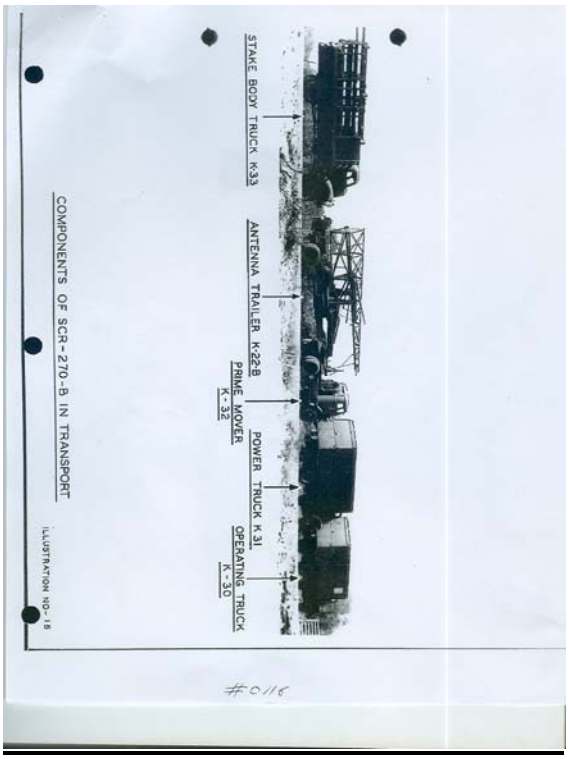
Appendix 13

Appendix 14

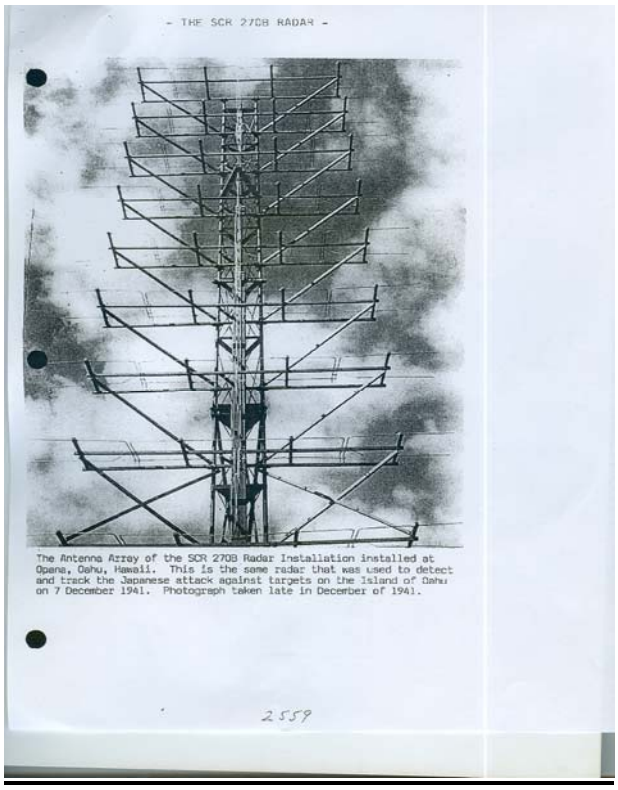


Appendix 15

Appendix 16



Appendix 17



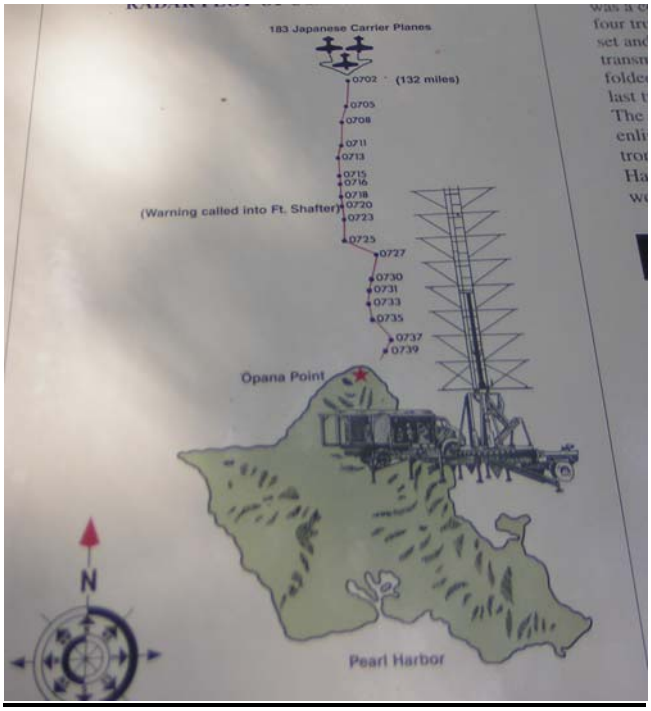
Appendix 18

Appendix 19

Appendix 20

Appendix 21

Appendix 22



Appendix 23