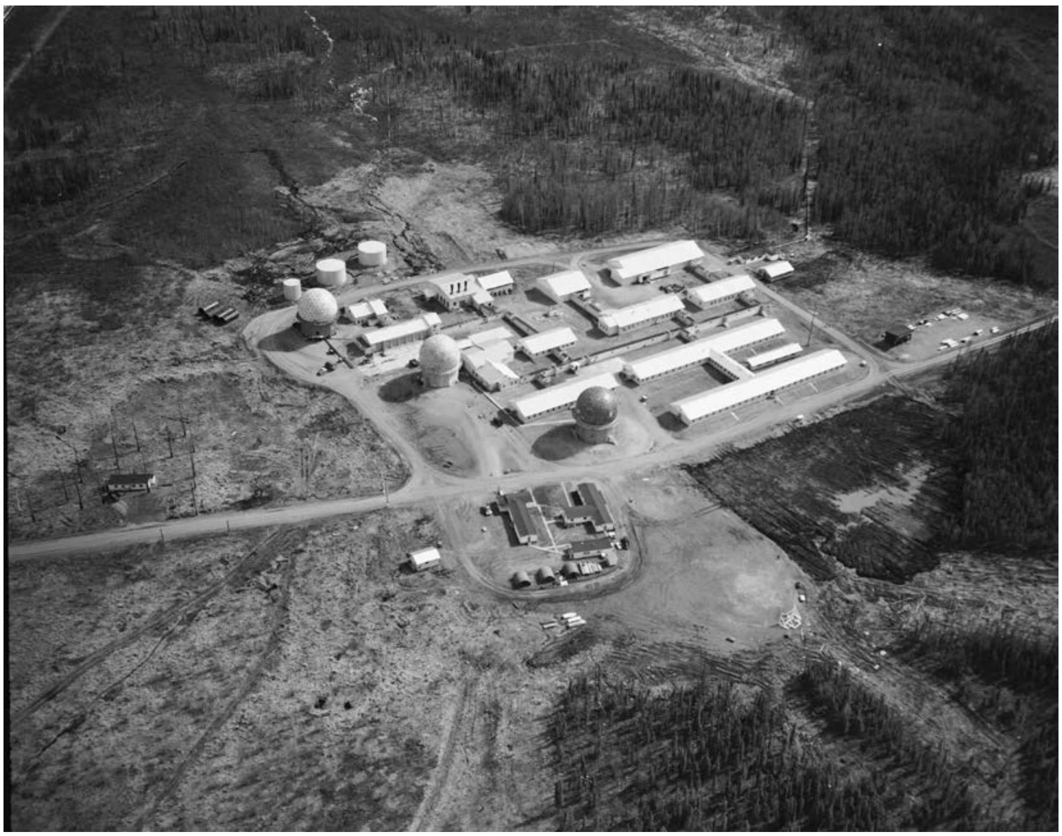
History of the Aircraft Control and Warning System in Alaska:
Air Defense of Arctic Skies



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Cover: Campion Aircraft Control and Warning Installation (1961).

TABLE OF CONTENTS

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ACRONYMS AND ABBREVIATIONS

The following is a list of the acronyms and abbreviations used in this document.

AAA	antiaircraft artillery
AAB	Army Air Base
AAC	Alaska Air Command
AB	Air Base
ABM	Anti-Ballistic Missile
ACHP	Advisory Council on Historic Preservation
ACWG	Aircraft Control and Warning Group
ACWS	Aircraft Control and Warning Squadron
AC&W	Aircraft Control and Warning
ADC	Air Defense Command
ADCC	air defense control centers
ADT	automatic detection and tracking
AF	Air Force
AFB	Air Force Base
ALASCOM	RCA, Alaska Communications, Inc.
ALCOM	Alaskan Command
ALSEAFRON	Alaskan Sea Frontier
AN	Army-Navy
ANG	Air National Guard
ANR	Alaskan NORAD Region
ARS	Alaska Radar System
AS	Air Station
ASG	Air Support Group
AWACS	airborne warning and control system
BMEWS	Ballistic Missile Early Warning System
BOMARC	Boeing-Michigan Aeronautical Research Center
CC	Commander-in-Chief
CEMML	Center for Environmental Management of Military Lands
CES	Civil Engineer Squadron
CINCAL	Commander-in-chief, Alaskan Command
CRT	cathode-ray tube
CW	continuous-wave
DEW	Distant Early Warning
EW	Early Warning
EWS	Early Warning System
FAA	Federal Aviation Administration

FD	frequency diversity
FM-CW	frequency-modulated - continuous-wave
FOB	forward operating base
GCI	ground-controlled interception
GE	General Electric
GOC	Ground Observers Corps
HABS	Historic American Buildings Survey
HF	high frequency
HO	History Office
ICBM	intercontinental ballistic missile
ISAR	inverse synthetic aperture radar
JBER	Joint Base Elmendorf Richardson
JCS	Joint Chiefs of Staff
JSS	Joint Surveillance System
LF	low frequency
LRRS	long range radar site
Lt.	lieutenant
MAD	mutual assured destruction
MAR	minimally attended radar
MARS	Military Affiliate Radio System
MHz	megahertz
MIT	Massachusetts Institute of Technology
mm	millimeter
MOA	Memorandum of Agreement
mph	mile per hour
MTI	moving-target indication
NATO	North Atlantic Treaty Organization
NCO	noncommissioned officer
NORAD	North American Air Defense Command
NPS	National Park Service
NRHP	National Register of Historic Places
NRL	Naval Research Laboratory
NSC	National Security Council
OTH	over-the-horizon
POL	petroleum, oil, and lubricant
PPI	plan position indicator
PRF	pulse repetition frequency

PX	post exchange
Radar	radio detection and ranging
RCA	Radio Corporation of America
RHI	range-height indicator
ROCC	Regional Operations Control Center
s	second(s)
μs	microsecond(s)
SAGE	semi-automated ground environment
SALT	Strategic Arms Limitation Talks
SAR	synthetic aperture radar
SCR	Signal Corps Radar
Sgt.	Sergeant
SHPO	State Historic Preservation Office
SLAR	side-looking airborne radar
SLBM	submarine-launched ballistic missile
SPASUR	Space Surveillance
SRRS	short range radar site
SSgt.	Staff Sergeant
STC	sensitivity time control
TACAN	Tactical Air Control and Navigation
TCG	Tactical Control Group
TWC	Tactical Contact Wing
TU-4	Tupolev-4
UHF	ultra-high frequency
US	United States
USSR	Union of Soviet Socialist Republics (Soviet Union)
USAF	United States Air Force
USARAL	United States Army, Alaska
USO	United Service Organizations
VHF	very-high frequency
WACS	White Alice Communications System

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PREFACE

The Aircraft Control and Warning (AC&W) System was one of the first technological defense systems developed by the United States during the Cold War. Constructed during the 1950s, the system consisted of a mixture of coastal surveillance early warning sites, interior ground control and intercept sites, and control center sites strategically located throughout Alaska along possible Soviet bomber approach routes. The AC&W System was designed to provide the United States advanced warning of a Soviet Union attack through aircraft surveillance and monitoring. It operated throughout the Cold War. In the late 1980s and early 1990s, select AC&W installations were modernized and updated with Minimally Attended Radar (MAR).

Today, eleven former AC&W stations have been updated to Long Range Radar Sites (LRRS) and operate within the Alaska Radar System (ARS) including Cape Lisburne, Cape Newenham, Cape Romanzof, Fort Yukon, King Salmon, Kotzebue, Indian Mountain, Murphy Dome, Sparrevohn, Tatalina, and Tin City. The ARS is managed by the 611th Air Support Group (611 ASG), a tenant on Joint Base Elmendorf Richardson (JBER) in Anchorage, Alaska. Each installation within the ARS is supported by a minimal number of contractor personnel.

In 1997, the 611 ASG determined the AC&W System eligible for inclusion on the National Register of Historic Places (NRHP). The Alaska State Historic Preservation Office (SHPO) concurred. Soon after, the United States Air Force and the Alaska SHPO entered into a Memorandum of Agreement (MOA), along with the Advisory Council on Historic Preservation (ACHP), to record the AC&W System's history and remaining facilities (611 ASG et al. 1997).

The following document summarizes the historic context of the AC&W System and is considered partial fulfillment of the terms of the 1997 MOA, which required architectural, photographic, and written documentation of the entire AC&W System.

The document is divided into several chapters. Chapter 1 summarizes the historical context of United States - Soviet relations that led to the development of the AC&W System and military buildup in Alaska. Chapter 2 presents the general history of the AC&W System including its development, construction, operation, integration with other systems, and decline. Chapter 3 examines each individual site and provides a brief history. Chapter 4 describes worker experiences at an AC&W site by relating personal recollections of individuals who were stationed at the bases while the radar system was in operation. Chapter 5 summarizes the eligibility of AC&W facilities in relation to the NRHP. Chapter 6 lists references used to complete the document. Additional information concerning the history, development, and operation of radars in general and AC&W radars in particular is provided in Appendix A. Finally, Appendix B contains brief biographic sketches of former AC&W personnel who provided personal recollections of their service in response to a survey conducted for this report.

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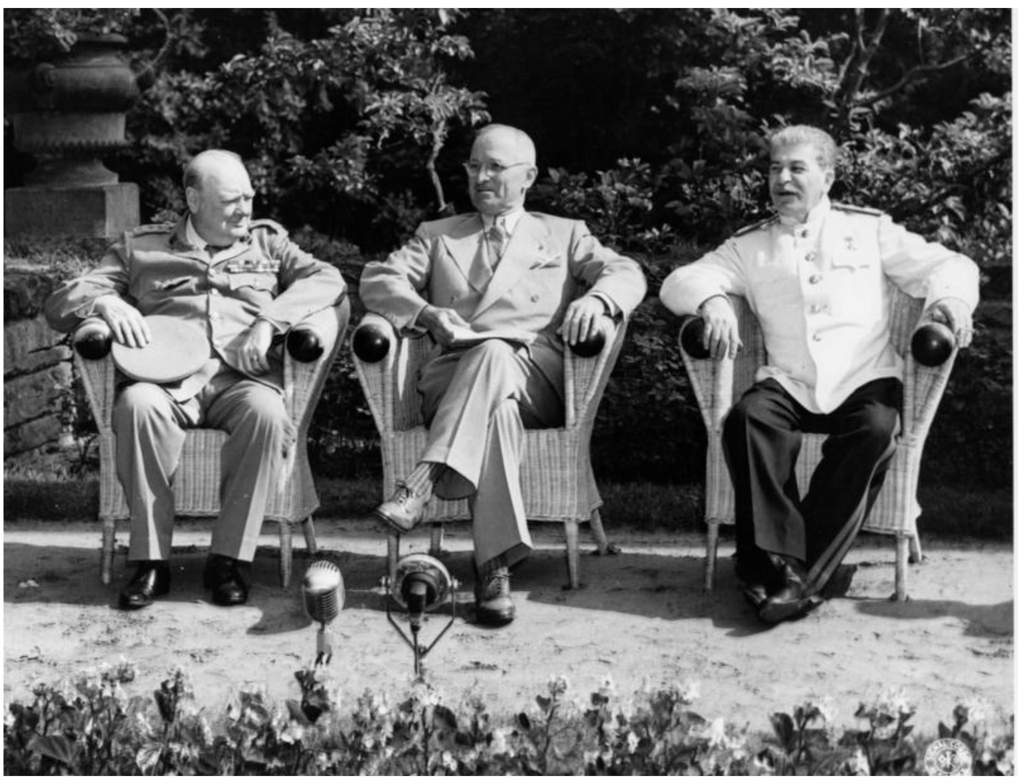
1 HISTORIC CONTEXT

1.1 GLOBAL EVENTS AND NATIONAL STRATEGIC CONTEXT

During World War II (1939-1945), the "Big Three" in the alliance against Germany, Japan, and Italy were the United States, Great Britain, and the Union of Soviet Socialist Republics (USSR or Soviet Union). Although tensions between the three were evident during the war, the Soviet Union, led by Joseph Stalin, was not seen as a significant threat until it began to subvert control of Eastern Europe by replacing coalition governments with communist rule (Djilas 1962).

Wartime alliances between the United States, Great Britain, and the Soviet Union ended soon after the Potsdam Conference in July 1945. Under post-war agreements (Yalta in February 1945 and Potsdam in July 1945), Europe was divided into two increasingly hostile camps: the non-communist, Western European camp and the communist, Eastern European camp.



Churchill, Truman, and Stalin at the Potsdam Conference. July 25,1945 (Source: Harry S. Truman Library and Museum).

In 1947, President Truman asked Congress to provide assistance to Greece and Turkey who were fighting communist insurrections backed by the Soviet Union. Truman saw the events as a much broader struggle between freedom and communist oppression indicating to

Congress, "It must be the policy of the United States to support free peoples who are resisting subjection by armed minorities or outside pressures" (Truman 1947). The statement, which later became known as the Truman Doctrine, resulted in $400 million in emergency military and economic support for Greece and Turkey. The Truman doctrine also became the rationale for a new foreign policy called "containment" established to stall the spread of Communism.

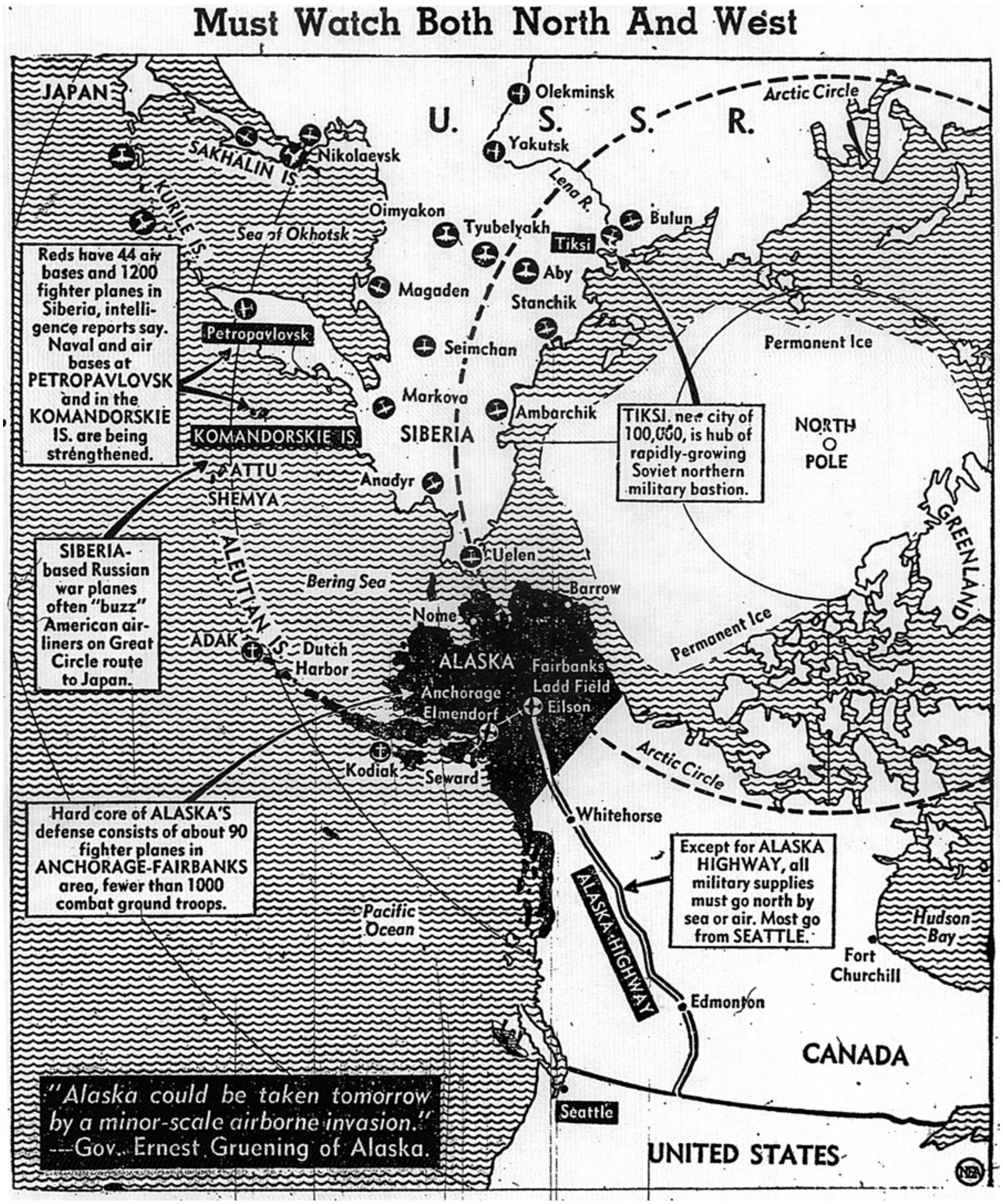
Western European countries agreed that the Soviet Union and its communist policies should be contained and formed the North Atlantic Treaty Organization (NATO) with the United States in April 1948 to counter Soviet aggression in Europe (Dupuy and Dupuy 1993).

One of the ways the United States was hoping to contain Soviet aggression was the threat of nuclear weapons. Toward the end of World War II, the United States possessed both nuclear weapons and a delivery system (in the form of long-range bombers). However, the threat of United States air power and nuclear weapons did not deter Soviet Union expansionism. Instead, it motivated the Soviet Union to develop its own nuclear weapons, long-range bombers, and missiles (Schaffel 1991; Stobridge 1966; Zaloga 1993).

The United States nuclear monopoly ended in the late 1940s/early 1950s. In 1947, the Soviet Union developed a bomber called the Tupolev-4 (Tu-4). Copied from American B-29s, the Tu-4 had a maximum range of 3,100 nautical miles and was capable of delivering bombs to the United States. Although not fully operational until 1949, the fact that the Soviets had the Tu-4 and were developing other strategic bombers pushed the United States into action. Both civilian and military minds began to explore the concept of continental defense and how to best protect the United States from the threat of nuclear attack and warfare (Holloway 1994; Sturm 1957; Zaloga 2002).

On August 29, 1949, the Soviet Union detonated its first atomic bomb. Truman announced the event to the American public on September 23, 1949. The realization that the Soviet Union had the capability to develop nuclear weapons and the means to deliver them (TU-4) was a major public concern. Soon after, Congress authorized funds for the sitting and station design of the Aircraft Control and Warning (AC&W) System. The AC&W System was designed to provide radar detection of Soviet bombers and to dispatch United States interceptor fighters in response to threats (Holloway 1994; Sturm 1957; Winkler 1997).

In early 1950, the Truman administration drafted an assessment of United States policy that called for a peacetime military mobilization to meet the international communist threat. However, it was the North Korean invasion of South Korea on June 25, 1950 that provided Truman with the opportunity to implement the mobilization policy. Once the Korean War began, existing air defense forces were placed on around-the-clock alert in expectation of a possible Soviet Union attack against North America. The United States also embarked on a major expansion of strategic nuclear and conventional forces around the globe. Of particular concern was the perceived vulnerability of North America, particularly Alaska, to Soviet Union bomber attack from Soviet bases west and north of Alaska (Ambrose 1993; Walker 1994; Schaffel 1991; Sturm 1957).



Map of Soviet Airfields north and west of Alaska, circa 1950 (Source: the *Forty-Ninth Star* a newspaper published in Anchorage, Alaska from 1946-1951).

In April 1952, an alert was called in response to a possible Soviet air attack. The attack turned out to be friendly commercial aircraft and unknowns, but it exposed deficiencies in the existing air defense system. That summer, a group of scientists from the Massachusetts Institute of Technology, (MIT) Lincoln Laboratory and other organizations met to discuss continental air defense. Known as the Lincoln Summer Study Group, most of their proposals were approved the following year by the National Security Council (NSC). Among their proposals was a recommendation to construct a system for early warning and interception as far north as possible across Alaska, Canada, Greenland, and Iceland. The system later became known as the Distant Early Warning (DEW) Line (Schaffel 1991).

The Air Force recognized early on the need for an advanced ground command and control communication system to effectively utilize warning systems in coordination with air defense missions. A 1949-1950 Air Force study recommended the use of a new technology, computers, to handle the job. The Air Force tasked MITs Lincoln Laboratory to study air defense in depth. In conjunction with RAND in Santa Monica, California, the Lincoln Laboratory developed the "semi-automated ground environment" (SAGE), a computerized network designed to coordinate all air defense components from processing radar signals to coordinating weapons used in battle. Operational in August 1958, SAGE was the world's first major command and control system to intensively utilize computers (Schaffel 1991).

Improvements in air defense weaponry kept pace. New types of fighter-interceptors, such as the F-86D Sabre (1953), the F-102 "Interim" Delta Dagger (1954), and the F-104 Starfighter (1956), were developed and deployed at United States and Canadian bases. As early as 1945, testing began on surface-to-air missiles (beginning with the Nike program). By 1953, batteries of Army Nike missiles were widely deployed. The Air Force settled on the Boeing-Michigan Aeronautical Research Center (BOMARC) missile, but technical difficulties delayed its deployment until 1959 (Schaffel 1991).

An F-102 Fighter-interceptor (Source: 11 AF Archives).

The growing effectiveness of American air defenses drove the Soviet Union to switch its priorities toward missile development. The Soviet Union tested a submarine-launched ballistic missile (SLBM) as early 1955, and, in August 1957 (two months before Sputnik), successfully test-launched an intercontinental ballistic missile (ICBM) with a range of approximately 4,000 miles (Zaloga 1993).

Once Sputnik was launched in October 1957, the United States shifted its focus from a Soviet bomber attack to ICBMs and began to develop an early warning system capable of detecting missiles. The Ballistic Missile Early Warning System (BMEWS) became operational in the early 1960s. Once the BMEWS was complete, the systems designed to detect bomber attacks (AC&W, DEW, etc.) were relegated a more subordinate role. BMEWS provided early warning of an ICBM attack, and the others provided advanced warning of bomber attacks, which would likely follow an ICBM attack (Ray 1965).

The rise of thermonuclear weapons, intercontinental strategic bombers, and ICBMs dominated the Cold War from the late 1950s on. Following the Cuban Missile Crisis of 1962 and the end of the Vietnam War in the early 1970s, there was growing alarm, on both sides, concerning the proliferation of nuclear weapons. In the early 1970s, the United States and Soviet Union began discussing limiting their arsenals and eventually signed the Strategic Arms Limitation Treaty (SALT I) of 1972, which sought to establish some control over excess nuclear weapons (Dupuy and Dupuy 1993).

Ronald Regan was elected President of the United States in November 1980. He immediately began fulfilling one of his campaign promises to rebuild American military forces and improve military balance. During the 1980s, the United States military was expanded. Many older military facilities were destroyed and replaced with newer ones, and new technology, such as strategic weapon systems and tactical weapons, were developed (Futrell 1989). It was during the mid-1980s that select AC&W sites were modernized and equipped with Minimally Attended Radars (MAR) to be used by the North American Aerospace Defense Command (NORAD).

In 1985, Mikhail S. Gorbochev became leader of the Soviet Union. Gorbochev rejected the policies of the past and indicated the Soviet Union would no longer intervene in Eastern Europe to maintain authority. In June 1989, free elections were held in Poland resulting in a communist defeat. Soon after, the governments of Hungary, East Germany, and Czechoslovakia were peacefully replaced with elections as well. On November 9, 1989, the Berlin Wall came down, and on December 3, 1989, during the Malta Summit, President George Bush Sr. and Gorbachev publicly acknowledged the end of the Cold War. A year later, on December 16, 1991, Gorbachev announced the Soviet Union would be dissolved into republics. By December 31, 1991, the Soviet Union ceased to exist (Walker 1994).

1.2 ALASKA STATE CONTEXT

1.2.1 Military Buildup in Alaska

During World War II, the chief military concern for Alaska was the western Aleutian Islands, where conflict with the Japanese lasted from June 1942 to August 1943. After the Japanese were driven from the islands in 1944, Aleutian forces and bases were reduced (Sturm 1957; Cloe 1996).

Soon after the end of World War II (1945), the military emphasis for Alaska began to shift from a Japanese threat in the western Pacific to a Soviet threat from the Arctic north. The Soviet Union, which lacked access to foreign bases within bombing distance of North America, established numerous airfields in northern Siberia beginning in 1945. Because these airfields were the shortest distance between the United States and the Soviet Union, Siberian bases represented the most important threat of Soviet attack on North America. United States military leaders perceived North America as vulnerable from the north, and in February 1946, Army Air Force Chief of Staff General Carl Spaatz enunciated what became known as the “polar concept” which placed air defense priority on the “polar approaches, namely the North Atlantic and Alaska” (Schaffel 1991:58).

The Eleventh Air Force (11 AF) managed combat and defense forces throughout Alaska during World War II. Many military installations were constructed during that time, primarily in the Aleutians. After the war, the Army began reorganizing its forces away from the Aleutians and onto mainland Alaska. The Alaskan Department re-designated the 11 AF as the Alaskan Air Command (AAC) on December 21, 1945 with headquarters on Adak Island at Davis Army Air Base (AAB). On October 1, 1946, AAC Headquarters was moved to Elmendorf AAB near Anchorage, Alaska. During the next several years, all of the World War II Army bases in the Aleutians, except for Shemya, were closed (Cloe 2008; Sturm 1957).

On January 1, 1947, the Alaskan Command (ALCOM) was established as a unified command reporting to the Joint Chiefs of Staff. ALCOM was comprised of the AAC, the Alaskan Department, later designated as the United States Army, Alaska (USARAL), and the Alaskan Sea Frontier (ALSEAFRON). Initially, AAC reported to Headquarters, Army Air Force. In July 1947, President Truman signed the Armed Forces Unification Act, which created the United States Air Force (USAF), making it equal to the Army and Navy. Once the USAF was created, the AAC reported to the Department of the Air Force. In recognition that the region was primarily an air theater of operations, the Commander-in-Chief, Alaskan Command (CINCAL) came from the general officer ranks of the USAF (Cloe 2008).

Arctic air defense units and equipment - aircraft, radar, and antiaircraft artillery (AAA) forces - were sparse during the first years of ALCOMs operations. The command had three squadrons (25 aircraft each) of World War II F-51H Mustangs (replaced by the F-80C “Shooting Star” in 1948) stationed at Ladd Airfield and Elmendorf Air Force Base (AFB) in Alaska, and Davis AFB located in Arizona. It activated a fourth squadron at Davis AFB equipped with twin-fuselage F-82 Mustang "night fighters" in late 1947, and moved the Davis AFB squadrons to Ladd and Elmendorf in 1948. ALCOM's early warning aircraft detection capabilities consisted of two aircraft control and warning squadrons operating World War II-era aircraft detection radars stationed at Ladd and Elmendorf. ALCOM established a single, AAA battalion but divided its assets between Ladd and Elmendorf AFBs in 1948, which represented ALCOM's first and only AAA force (Schaffel 1991; Strum 1957).

An F-80 "Shooting Star" Fighter Interceptor Aircraft assigned to the 66th Fighter Interceptor Squadron. The picture was taken at Elmendorf AFB in February 1950 (Source: 11 AF archives).

Hampered by a lack of personnel, underpowered radar equipment, and unreliable communications, the early aircraft warning system was marginal at best. From 1946 to 1949, the Air Force put forth various plans to upgrade Alaska's air defenses, but both the Department of Defense and Congress were reluctant to authorize funding.

Until funding was approved, the AAC created an interim radar system consisting of outdated World War II radar equipment relocated from Aleutian bases along with limited fighter and antiaircraft forces. Temporary, mobile radars were installed at Bethel, Clear, Elmendorf, Farewell, Galena, Gambell, Kotzebue, Ladd, Naknek (King Salmon), and Nome. The temporary radar system, in Alaska and other areas of the United States sites, was known as "Lash-up" (AAC 1953; Strum 1957).

In 1949, Congress approved approximately $86 million for a national early warning radar system, $31 million of which was appropriated to the AAC to develop a permanent radar defense system in Alaska. The appropriation was prompted, in part, by the detonation of the Soviet Union atomic bomb in August 1949. Alaska's system, known as the AC&W System, was constructed between 1951 and 1954. Originally, it consisted of 12 radar sites and 2 control centers located in both perimeter and interior sites across Alaska. Six additional sites were added in 1958 (AAC 1953; Cloe 2008; Winkler 1997)

Although the United States had taken steps toward developing a continental defense, there was still concern that air defenses were inadequate. In the early 1950s, several studies were conducted to determine the best course of action. Studies, such as the 1952 Lincoln Summer Study Group, recommended the construction of an early warning radar system across the Arctic called the DEW Line that would provide three to six hours of advanced warning of an attack from the north. In 1953, the Department of Defense began developing and testing the feasibility of radar and communications in the Arctic. By the summer of 1954, the equipment and an experimental test line across northern Alaska were determined feasible, and the DEW Line was extended east across northern Canada. The DEW Line became operational in 1957. In the late 1950s and early 1960s, the system was extended west across the Alaska Peninsula and the Aleutian Islands and east across southern Greenland (Schaffel 1991).

High-frequency radio communications were initially used to link AC&W sites, DEW Line sites, and their control centers, but the system proved to be unreliable. In 1954, Bell Electric Systems was asked to recommend a new communications network. Bell recommended a forward propagation tropospheric scatter or "tropo" system called the White Alice Communications System (WACS). WACS, which was constructed between 1955 and 1957, vastly improved communications links between radar sites and successfully linked sites of the AC&W system and the DEW Line into a cohesive network, relaying communications back to control centers and Elmendorf AFB. Many of the original 31 WACS sites were collocated at AC&W and DEW stations (Reynolds 1988).

In August 1957, the Soviet Union announced a successful ICBM launch. The United States quickly shifted focus from defending against a bomber attack to defending against a missile attack. NORAD, established in August 1957 to provide joint air defense of the North American continent, identified the need for a BMEWS. The Air Force began constructing the BMEWS with sites at Clear, Alaska, Thule, Greenland, and Flyingdale Moor, England. The sites became operational in 1961 (Cloe 2008).

As a whole, the 1950s was a decade of military buildup in Alaska. The military spent more than $1 billion dollars on construction during the decade, mostly between 1951 and 1958, primarily to develop an integrated defense system and bomber early warning network. The expansion of Alaska's defenses was a direct response to the advance of Soviet military capabilities and, most immediately, to the Korean War. Along with northern Canada, Alaska assumed the role of advance warning for North America. The military post at Anchorage was enhanced in 1950 when it was divided between the Air Force at Elmendorf AFB and the Army at Ft. Richardson. An Alaska Air National Guard (ANG) airbase was built beside Anchorage International Airport in 1955. The Army was responsible for ground and antiaircraft defense, especially in the vicinity of Anchorage and Fairbanks. It also operated the cold weather training school and laboratory at Fort Greely near Fairbanks. The Navy, based at Kodiak and Adak, ran maritime patrols on the sea and in the air, establishing an air-sea "picket line" on the Great Circle Route. The Air Force's mission included radar and aerial interception. Civilian Alaskans also played a direct defense role as volunteers (1,000 of them) in the civilian Ground Observers Corps (GOC), formed in 1953 to watch for enemy aircraft in the skies (Denfeld 1994; Schaffel 1991).

Toward the end of 1950, fighter-interceptor squadrons began to receive improvements in their obsolete aircraft when the first all-weather, radar-equipped, F-94 jet fighters arrived at Ladd. In mid-1951, squadrons at Elmendorf received the Lockheed F-94As. The Northrop F-89 Scorpions, which were twin-engine, all-weather, fighter-interceptors, arrived between late 1953 and mid-1954. The Convair F-102 Delta Dagger, a fully-modern, supersonic, all-weather interceptor, was introduced in 1957 (11 AF Archives; Sturm 1957).

An F-94 Aircraft. F-94 aircraft arrived toward the end of 1950 and were radar-equipped (Source: 11 AF Archives).

In 1952, AAA batteries were sited at Anchorage and Fairbanks to protect the military bases. Major gun improvements came with the assignment of the 75-mm Skysweeper in 1954 to the Eielson and Elmendorf batteries. Eielson and Ladd also received 120-mm guns in 1956, while one battalion at Elmendorf continued with the older 90-mm guns. Overall, AAA forces increased from three to five battalions between 1950 and 1956. By 1957, plans were drawn up for equipping the non-Skysweeper battalions with Nike missiles (Sturm 1957).

An F-89 "Scorpion" Fighter Interceptor Aircraft. F-89 Scorpions, arrived at Alaskan bases between late 1953 and mid-1954 (Source: 11 AF archives).

The late 1950s represented the peak of military involvement in Alaska during the Cold War. Although many forces remained in Alaska for the duration of the Cold War, the military dominance of the social and economic landscape of Alaska declined, and other industries replaced the military as the backbone of the state's economy and principal source of its population.

1.2.2 Economic Effects of the Military Buildup in Alaska

Prior to World War II, the military had little involvement in Alaska. However, military activities during World War II transformed Alaska through improvements in infrastructure and infusion of people. From the early to mid-1940s, the federal government spent more than $1 billion in Alaska modernizing the Alaska Railroad, expanding airfields, and constructing roads, which benefited the war effort as well as the civilian population (Naske and Slotnick 1987).

Military construction during the Cold War had an even more dramatic effect on Alaska than did events of World War II. The military constructed or significantly improved roads, railways, communications systems, housing, and sea ports. By 1966, ALCOM had a $2 billion investment in Alaska. The military's annual operational expenditure exceeded $290 million, which made a significant contribution to the Alaskan economy. In the mid-1960s, over half the total population in Alaska consisted of federal employees and their dependents, with military personnel comprising 78,000 of the 250,000 people in Alaska (Stobridge 1966).

Massive military spending in Alaska stimulated tremendous economic growth. From World War II until at least the mid-1960s, military construction, garrison maintenance, and an influx of uniformed personnel along with their dependents made the military the major single element in the economic growth of Alaska. Compared with prewar expenditures of less than $1 million in the territory, military spending peaked at $512.9 million in 1953 and amounted to $354 million in 1970 (Naske and Slotnick 1987).

Nearly half of Alaska's economic base between 1950 and 1957 was directly linked to military spending. Total income for this period was $600 million, of which 19 percent was from contract construction and 21 percent from military income payments (Rogers 1962). Consumer spending by military personnel and their dependents further increased the military contributions to Alaska's income.

Federal government employment in Alaska peaked in 1967 (51,000 people) and declined to less than 45,000 by 1973. Most of the fluctuations in federal employment were attributable to changes in the number of military personnel stationed in Alaska. Civilian employment by the military remained essentially constant at a little more than 17,000 after the mid-1960s (Kresge et al. 1977).

Numbers of military personnel in the state, while still significant, began to decrease in 1960. From a peak of 48,563 military personnel in Alaska in 1952, the number began a steady decline. By 1960, only 32,606 personnel were stationed in the state. The seemingly sudden decrease in military personnel (due largely to the shifting priorities in the Cold War and the decreased emphasis on bomber warning), was a cause of great concern to Alaska's citizens and Congressional delegation (Rogers 1962). A small number of personnel (1,300) were stationed in Alaska to staff the newer missile early warning and defense station that became operational at Clear, Alaska, in 1957, but the overall trend has been a decline in military personnel since the 1960s.

1.2.3 Social Effects of the Military Buildup in Alaska

The military also had a significant effect on the social landscape of Alaska. It brought in a large influx of people who were accustomed to services and standards of living available in the lower forty-eight states. The new people demanded similar services in Alaskan towns and shaped the growth of the territory, particularly its cities, from frontiers to modern communities (Naske and Slotnick 1987).

Because of the vast geography, harsh terrain, and remoteness of many villages in Alaska, the military played a large role in the development of other social services as well. Until 1971, the military operated Alaska's telephone and telegraphic communication system. The services offered included telephone and telegraph messages, telegraphic money order transfers, lease of communications channels and station apparatus, coastal marine service, press service to newspapers and radio-TV stations, radio program service, and rural telephone service to subscribers adjacent to existing open wire lines. The military also assisted with disaster relief, emergency rescues, wildlife conservation, and other atypical activities, particularly before Alaskan statehood in 1959. After statehood, military contributions of manpower, equipment, and supplies to Alaska's communities decreased by half between 1960 and 1961. However, the military continued to play a critical role in assisting with natural disaster recovery efforts (Stobridge 1966).

2 AIRCRAFT CONTROL AND WARNING SYSTEM HISTORY

2.1 Aircraft Control and Warning System: 1951 to 1965

Over a period of 40 years, the military constructed several integrated radar, communication, and navigational systems in Alaska. One of the first of these after World War II was the Aircraft Control and Warning (AC&W) System, which is the focus of this document. Operation of the AC&W system began in 1951. It was followed shortly thereafter by the Distant Early Warning Line (DEW) Line, the White Alice Communications System (WACS), the Tactical Air Control and Navigation (TACAN) System and the Minimally Attended Radar (MAR) System. The systems worked as a network, and each facility was a component of an overall warning system providing surveillance and monitoring against Soviet Union bombers for the North American continent.

2.1.1 Conception and Planning

At the end of World War II, there were 13 radar installations in Alaska, primarily located in the Aleutian Islands. The temporary World War II radar system had been designed with a 10-year life expectancy and gave reliable coverage, over water, to ranges of up to 200 miles. However, because of geographic barriers and land contours, coverage over land areas was ineffective at distances greater than 50 miles (11 AF 1996a).

Given the inadequacies in the Alaskan radar network, the Commanding General, Alaskan Department, directed the Eleventh Air Force (11 AF) to develop a radar plan for defending Alaska in May 1945. At the time, there was no funding for a new radar system. For that reason, a total of six radar stations (located at Elmendorf Air Force Base [AFB], Clear, Nome, Naknek, Galena, and Gambell) and two control centers (located at Elmendorf AFB and Ladd AFB) were recommended using radar equipment removed from the Aleutian Islands. The interim air defense system was manned by approximately 440 personnel and provided air defense coverage for Alaska until a permanent solution was found (AAC 1951; AAC 1953; Cloe 2008).

When establishing a permanent radar system, the Army was faced with the decision of whether to rely on an outer warning screen around the perimeter water areas (giving no interior coverage for tracking attacking aircraft), or to establish a more compact land radar detecting system projecting a much shorter distance away from the vital areas (Allen 1992; 11 AF 1982; Reynolds 1988). The second option provided more complete coverage, with accurate tracking that allowed for controlled interception. On the basis of the speed of military aircraft at that time, the radar system was designed to provide a 1-hour warning to defending forces. Military planners thought this warning time would be sufficient to prepare for defensive operations.

In the late 1940s, four separate studies were completed to determine Alaska's defense needs and the feasibility of a permanent radar system. The first study was conducted in mid-1946 by the Army-Navy "Hoge" Board to determine the joint air defense needs of Alaska. The board recommended construction of 36 radar sites in Alaska, ten of which would operate during peacetime (Cloe 2008).

The Hoge Report was the first large study for post-war radar systems in Alaska. Four of the 36 systems recommended by the Hoge Report were to be AN/CPS-6 units, and 32 were to be AN/CPS-5. The AN/CPS-5 was developed by Bell Telephone Laboratories and General Electric. Production of the radar began in 1945. It was designated as a transportable, medium-range search radar and could be operated with a crew of 10. The AN/CPS-6 (A and B) was developed during the later stages of World War II by the Radiation Laboratory at Massachusetts. It took 25 people to operate the radar. It was often referred to as being "heavy," and the equipment for a single AN/CPS-6B system filled 85 freight cars. Both the AN/CPS-6 and AN/CPS-5 systems had capabilities to determine the altitude of an aircraft. The Hoge Report, although very detailed, did not specify any associated costs or specific personnel requirements.

The second study was conducted by the Alaska Air Command (AAC) from 1946 to 1947. In December 1945, the 11 AF was re-designated the AAC and the planning organization for Alaskan radar. Reorganization of the military forces in Alaska and subsequent cutbacks in personnel allotments affected radar planning in the area. The AAC study (called "Radar Sites and Radar Coverage in the Alaskan Department") developed an entirely different strategy from the Hoge Report for protecting Alaska (Cloe 2008). The AAC started its analysis by dividing the entire Alaskan Territory (Alaska did not become a state until 1959) into regions and recommended a total of 58 radar stations to cover these regions. The AAC recommended using the AN/CPS-1 or the AN/CPS-6 radar systems, or their equivalents, for the installations.

The third study was conducted in 1947 by the Army-Air Force. Lieutenant Colonel Harold J. Crumly led a small team to investigate the potential for ground radars in Alaska and the Aleutians. In particular, the team was searching for site locations that could ensure adequate warning for all defense elements against low-level air attack. The team was looking for locations that would provide sufficient low-altitude coverage to permit interception at the greatest practicable range. The Crumly Report called for 13 radar sites and three control centers in the Alaskan interior to provide an inner ring of defense and 13 perimeter sites along the coast of Alaska to provide early warning. Control stations would be manned with approximately 23 officers and 260 enlisted men. Smaller stations would be manned with 5 officers and 85 enlisted personnel (AAC 1953; Cloe 2008).

In late 1947, the newly created United States Air Force conducted a fourth study addressing a radar system in Alaska and the entire the United States. The study incorporated all previous reports. Project Supremacy, as it was known, called for the development of a national early warning radar system consisting of 374 radar stations and 14 control centers located throughout the continental United States, with 37 of the radar stations and 4 of the control centers located in Alaska (Cloe 2008; Denfeld 1994; Winkler 1997).

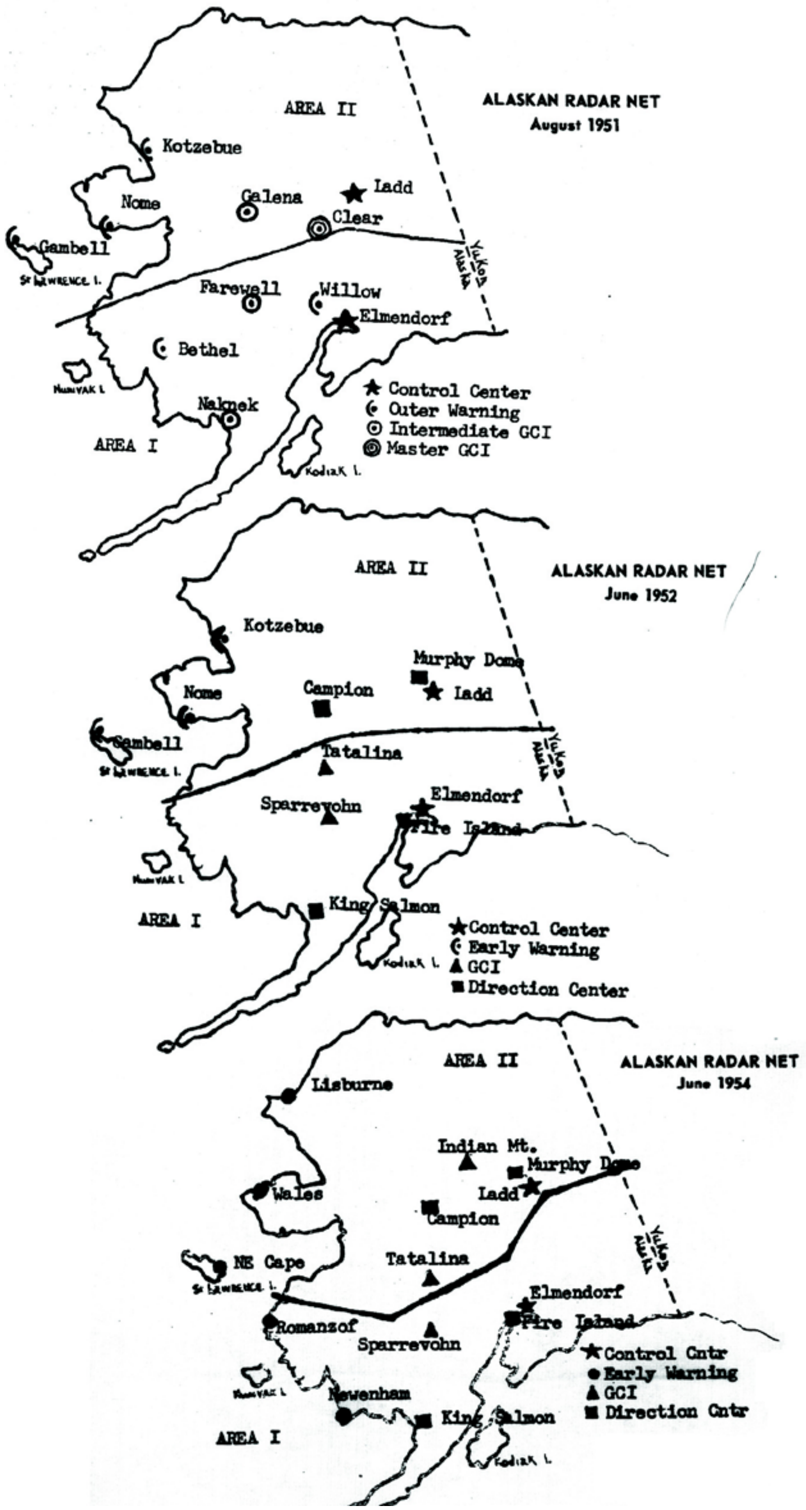
The estimated cost of the system ($400 million) was determined too expensive and a scaled back version was ordered. The scaled back version, called the Modified Plan, reduced the number of radar sites to 75 and 10 control centers throughout the continental United States, with 10 of the radar sites and 2 control centers located in Alaska. The Modified Plan passed Congress in the spring of 1949 for an estimated cost of $86 million, $31 million of which was appropriated to the AAC to develop a permanent radar defense system in Alaska. The target year for completion was 1952 (AAC 1953; Cloe 2008; Denfeld 1994; Winkler 1997).

Concerned about the Soviet Union detonation of an atomic bomb in 1949, the United States developed an interim radar system, called Lash-up, using World War II vintage radar antennas. In Alaska, the Lash-up System consisted of existing radar stations located at Clear, Naknek, Nome, Elmendorf, Galena, and Gambell plus three emergency stations at Kotzebue, Bethel, and Farewell . The Lash-up System was marginal, at best. Although not obsolete, the AN/CPS-5 radar units at the sites experienced frequent outages and lacked "moving target indication" (MTI) capability, and the AN/TPS-1B units were limited in range. In addition, radio communications were unsatisfactory and subject to long periods of outage due to ionospheric conditions. Tests performed in August and October 1950 indicated the system was vulnerable to aircraft attack, primarily because of ineffective communications and equipment that was inoperable due to maintenance problems (AAC 1953; Winkler 1997).

2.1.2 Construction

In accordance with the Modified Plan, Congress appropriated $31 million to the AAC for the construction of 10 radar sites and 2 control centers. The AAC began construction of its radar defense system, known as the AC&W System, in the early 1950s with installations strategically located along probable Soviet bomber approach routes. The AC&W System was a mixture of coastal surveillance early warning (EW) sites, interior ground control and intercept (GCI) sites, and air defense control centers (ADCC). The first two sites constructed were located at Murphy Dome and Fire Island. The sites, which became operational in 1951, served as master GCI stations. The next three stations were interior GCI sites located at Naknek (King Salmon), Campion, and Takotna (Tatalina). The remaining five stations, located at Cape Lisburne, Cape Romanzof, Tin City, Northeast Cape, and Cape Newenham were coastal surveillance EW sites. Elmendorf AFB and Ladd AFB served as ADCC. All 12 were operational between 1951 and 1954 (AAC 1953; 11 AF 1996a; Cloe 2008).

As a result of the outbreak of the Korean Conflict in June 1950, the military received a substantial budgetary increase. The AAC was granted funding for two additional ground control intercept installations to cover radar gaps in the interior of Alaska. The sites, located at Indian Mountain and Sparrevohn, became fully operational in 1954. During the late-1950s, six additional surveillance sites were added at Bethel, Fort Yukon, Kotzebue, Middleton Island, Ohlson Mountain, and Unalakleet. They became operational in 1958 (Cloe 2008)

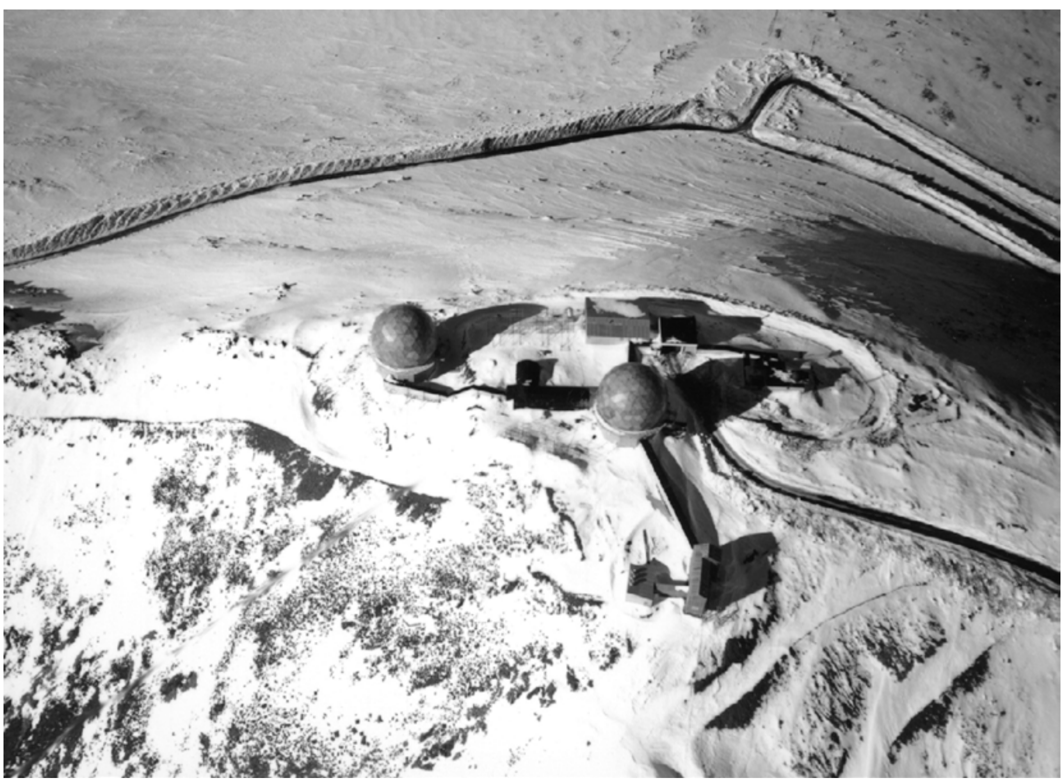


Radar Development and Planning Maps. Original maps from historic Air Force planning document (circa 1950) showing the proposed development of the AC&W installations (Adapted : Argonne National Laboratory 2002a).

The early years, 1949 to 1952, were very difficult for the AAC. The command was severely strained by the necessity to provide facilities for its forces. Major construction efforts were required just to permit full deployment of all forces allocated to the command by the Joint Chiefs of Staff (JCS) (Stobridge 1966).

Construction of AC&W facilities also posed a number of potential problems for the AAC. For example, constructing steel radar towers in Arctic terrain was an engineering challenge due to both the extreme weather conditions that hampered construction and the difficulties associated with designing foundation systems on permafrost. Permafrost can melt if additional heat is applied by the building or structure. When the permafrost melts, the foundation can lose stability. In addition, construction crews worked round the clock during the summer. Shift workers shared quarters, with two, sometimes three, men using the same bed at different hours in the day. Long hours and personnel shortages often led to safety hazards.

For the first time, radar stations were standardized with respect to manning, facilities, and equipment. All GCI interior stations (Campion, Tatalina, and Naknek) were to have identical quarters, search capability, and strength. Each site provided facilities for 8 officers and 104 enlisted men, sufficient warehousing and petroleum, oil, and lubricant (POL) storage for extended periods, an AN/CPS-5 unit to be eventually replaced by an AN/FPS-3, air-ground and radio communications, and a very-high frequency (VHF)



Tatalina (circa 1950s). Aerial view showing a typical AC&W station layout. The radomes, support buildings, and connecting passageways can be seen (Source: 11 AF archives).

direction finder. The EW sites along the coast (i.e., Tin City, Cape Lisburne, Cape Romanzof, Cape Newenham, Northeast Cape) were also standardized. The perimeter stations were to be manned with 4 officers and 85 enlisted men, sufficient warehousing and POL storage, one AN/FPS-3 set, air-ground VHF communications, and radio circuits. The master control stations at Murphy Dome and Fire Island would each be manned by 26 officers and 226 enlisted men, equipped with an AN/CPS-6B radar unit, and furnished with appropriate communication equipment. Operating personnel at ADCC were limited to approximately 170 personnel (AAC 1953).

2.1.3 Design Issues

During construction and testing activities in 1951, it became clear that the radar equipment had to be protected from the damaging effects of the wind and heavy icing. Sparrevohn became operational with interim equipment (AN/CPS-5) in December 1951. Days later, winds blew the antenna down and damaged the set. To minimize the impacts of wind and icing, radomes were deemed to be essential. The material used in constructing the radomes was chosen so that the domes produced a minimum amount of attenuation to the radar beam and would be able to withstand the highest velocity winds (120 mph) in mountainous areas (Cloe 2008).

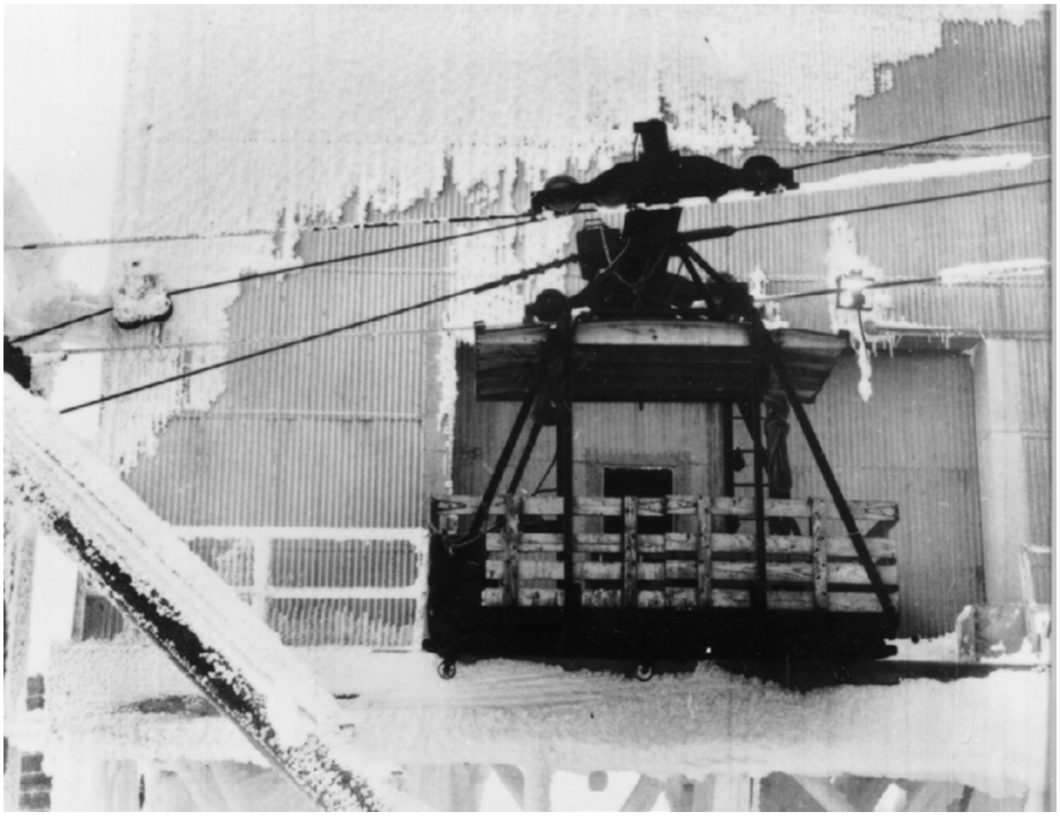
A typical early AC&W radar installation without a protective radome - probably the AN/CPS-5 at Sparrevohn circa 1951. Radar antenna were housed in radomes to protect them from powerful winds, ice, and snow (Source: 11 AF archives).

The AAC also stipulated that any station additions to the radar network should take the following factors into consideration:

- Mann sites around 135, plus or minus 10.
- Prefabricated construction should be used, and consolidated facilities with heat and power should be used whenever possible.
- Stations should be located near a water supply.
- Operations buildings should be located adjacent to the radar tower.
- All-weather roads, rather than trams, should be used for transportation at individual sites to lower costs.
- Proposed sites should be equipped with AN/FPS-3 and AN/FPS-6 radar systems.
- Receiver/transmitter facilities should be located away from the site on high terrain.
- Use of airstrips for logistical support should be considered (Cloe 2008).

Several of the sites had tramways connecting top and bottom camps (Cape Lisburne, Cape Newenham, Cape Lisburne, Cape Romanzof, Tin City). When in proper working condition, the trams were vital tools in moving supplies, equipment, and personnel from bottom base camps to the tops of mountains where the radar units were installed and operated. The trams were difficult to maintain, especially during severe weather. If the tram was not operational due to maintenance issues or during winter storms, top camps could be isolated for periods of several days or more (Cloe 2008).

Cape Newenham (circa mid-late 1950s). The bottom camp provided living quarters and administration. The top camp contained the radomes and associated facilities. (Source: 11 AF archives).



The Tin City Tramway (circa mid-late 1950s). Trams provided a means for the servicemen to move from the bottom, or base, camp to the top camp where the radar was located. Under severe weather conditions, tram operation could be difficult, and the top camps could be isolated for periods of several days or more (Source: 11 AF archives).

In addition to the above standardizations, the early 1950s brought about improvements in communications networks, a vital linkage between perimeter stations and control points. Up to and including 1950, point-to-point communication was primarily limited to high frequency (HF) and low frequency (LF) radio. In 1950, outage time averaged more than 20 percent, and during one week in October, three essential circuits were virtually useless because of atmospheric conditions. In late 1951, the AAC began conducting communication tests, called Opportunity Strikes, to determine if VHF could be used for point-to-point communications between AC&W sites. Operation Strikes was determined successful in late 1952. Alaskan air defense communication was improved immensely by the addition of VHF communication, completion of the Tok-carrier circuit (i.e., a telephone-teletype circuit between Anchorage and Fairbanks) in 1952 that allowed voice communications, and the deployment of combined VHF-microwave relay stations (Cloe 2008).

2.1.4 Radar Equipment and Upgrades

Early AC&W sites were initially equipped with AN/CPS-6B, AN/CPS-5, and AN/FPS-3 radars. The AN/CPS-6B was a World War II search and height finding radar able to detect aircraft at 100 miles and 16,000 feet. The AN/CPS-5 was a World War II search radar able to search up to 60 miles at 40,000 feet. It was often paired with an AN/TPS-10B height finding radar. The FPS-3 was a modified version of AN/CPS-5 radar with a search range of 200 miles and altitude detection up to 65,000 feet (Winkler 1997).

By 1954, improvements in the system were called for due to concerns about a new Soviet high-altitude jet bomber. One of the most promising improvements appeared to be the GPA-27 device, which included a klystron tube that offered the possibility of increasing the range of the FPS-3 by 5 to 10 percent. The improved radar was designated FPS-3A. Another component, the OA-347, which included the QK-254 magnetron tube, promised to increase the range of the AN/CPS-6B by as much as 65 percent. After installation, however, it was discovered that the magnetron tube could not deliver the anticipated 2 megawatts of power reliably, and failures occurred frequently above a power of 1.5 megawatts. With considerable effort, replacement tubes were made available, but improvements were less than anticipated (McMullen1966). Later AC&W sites, operational in 1958, were equipped with AN/FPS-3 search radars and paired with AN/FPS-6 height finding radars or AN/FPS-8 search radars paired with AN/FPS-4 height finding radars (Winkler 1997).

2.1.5 Operational Challenges

Accessibility of AC&W locations provided operational challenges. The installations were sited to provide the best radar coverage, which meant they were often in remote locations, far from any developed infrastructure. Only major military installations in Alaska (Elmendorf, Eielson, Forts Wainwright, Fort Richardson, and Clear) were accessible or serviced by rail. Two AC&W sites could be reached by road (Murphy Dome and Ohlson Mountain). Two were accessible only by air (Indian Mountain and Sparrevohn), and the remaining remote AC&W were accessible by air and by water during the summer.

Each AC&W installation required a staff of up to 250 personnel to operate the radar systems, perform maintenance, and provide support. The Sparrevohn and Indian Mountain installations, which were accessible only via air, were resupplied by air on a year-round basis (Alaskan Air Command Comptroller 1982). The other AC&W installations were supplied by barge via ocean or river. The harsh arctic winters limited water resupply to the summer.

Resupply of the remote sites was one of the greatest challenges for the AAC. Because resupply was an annual event for most of the sites and the window of delivery was severely limited by weather conditions, resupply operations required extensive planning. The first experimental resupply program via sea was conducted in 1951. Items were shipped via Seattle to seaports in Alaska. The seaports then shipped the cargo via barges to the remote sites (Alaskan Air Command Comptroller 1982).

By 1953, the resupply mission had become so important to the Alaska defense system that AAC code named it Mona Lisa. From 1953 until 1966, the Mona Lisa program provided annual resupplies to the remote sites. In December 1966, Mona Lisa was renamed the Cool Barge Resupply Program. Cool Barge continued to provide bulk items to the installations, while fresh foods, equipment parts, and other necessary items were delivered via airlift on a daily basis. The annual resupply program by barge was discontinued to the remote sites in 1995 (Alaskan Air Command Comptroller 1982, Cloe 2008).

A Mona Lisa (later Cool Barge) summer resupply barge circa late 1950s/ early 1960s (Source: 11 AF archives).

When it was operating, the annual resupply started in Seattle and involved all branches of the service. The Air Force procured supplies and oversaw the loading onto Navy barges. The Navy sealifted the cargo to coastal sites. The Army loaded supplies onto smaller barges and transported them to the beach, and finally, at the AC&W sites, Air Force personnel unloaded the barges and transported the cargo to their storage areas. Initially handled entirely by the military, many aspects of the resupply mission were contracted with commercial entities after 1957 (Cloe 2008).

Supply shortages plagued the AC&W sites throughout their operations but were particularly acute in the early years. Shortages affected all areas of operation, including spare parts for maintenance of equipment, as well as supplies of fresh food and water. Also notable were shortages of post exchange (PX) items due to the lack of priority, and delayed air shipments due to inclement weather. Noted in a 1955 history, one unit was needed to keep very close check on PX supplies, particularly "with the influx of civilian personnel to this station at various times..." (711 ACW 1955:19-20).

Unloading Mona Lisa (later Cool Barge) supplies at an unknown site circa 1960s (Source: 11 AF archives).

In addition to supply issues, AC&W sites experienced weather related challenges as well. Severe winds, extreme cold temperatures, snow, and persistent darkness in winter months created an often dreary work environment. These conditions also created problems with mechanical operations. Tramways were often inoperable because of wind. Water shortages and frozen pipes created problems with water supply and sewage treatment. Water storage was sufficient but continually suffered problems with freezing during the winter, especially at the more remote bases. Sewage systems froze as easily as water supply systems. At Tin City, it was reported, several times, that the sewage disposal system at the radome site became inoperative because of a frozen drain.

Wind and cold created problems for men traveling outdoors at many of the sites during the winter. All personnel were issued arctic gear, and local travel restrictions were imposed during storms. Conditions sometimes stranded men at installations in which top and bottom camps were separated. Consequently, food and other supplies were maintained at top camp for times when travel was impossible. Wind also wreaked havoc on the buildings and required expensive maintenance. Buildings that were not maintained at abandoned AC&W locations quickly fell into disrepair from the elements.

2.1.6 Other Alaskan Radar Developments

Although the United States developed the AC&W System, there was still concern that continental air defenses were inadequate. In the summer of 1952, a group of scientists from throughout the United States and Canada gathered to study the issue of continental defense.

They met at the Lincoln Laboratory, the air defense laboratory of the Massachusetts Institute of Technology (MIT) and called themselves the Summer Study Group. The Summer Study Group recommended improvement of the national air defense system including a recommendation to construct an early warning radar system in the Arctic called the DEW System. If located far enough north, the DEW System would provide three to six hours of advanced warning to intercept and/or retaliate (Jockel 1967; MIT, Lincoln Laboratory 1953; Ray 1965).

Tatalina Top Camp Access Road (January 1960) (Source 11 AF archives).

The Summer Study recommendations were approved and the DEW Line was constructed across northern Alaska and northern Canada between 1953 and 1957. In the late 1950s and early 1960s, the system was extended west across the Alaska Peninsula and the Aleutian Islands and east, across southern Greenland.

In August 1957, the North American Air Defense Command (NORAD), a joint United States-Canadian command, was informally established to provide air defense for the North American continent. The agreement was formally ratified in May 1958. In June 1958, Alaska was incorporated into the NORAD as the Alaskan NORAD Region (ANR). The ANR was responsible for the air defense system that had been in place in Alaska since the early 1940s. In addition to its responsibility for the air sovereignty of Alaska, the ANR controlled 18 AC&W installations, an Aleutian DEW Line Sector, 2 Nike Hercules air defense missile battalions, and 6 fighter interceptor squadrons (11 AF 1996b, Cloe 2008).

2.1.7 Integration with Forward Operating Bases

Once complete, the AC&W System consisted of 18 permanent sites located throughout Alaska. AC&W radar sites provided the "eyes" to detect incoming Soviet Union bombers. Fighter-interceptor aircraft, located at forward operating bases (FOBs) could be deployed to intercept the intruding aircraft, and a communications network was developed to provide direction and coordination among the sites.

Fighter-interceptor aircraft directed by the AC&W sites were deployed at two primary FOBs: King Salmon (Naknek) and Galena. The airports located at both FOBs were originally constructed during World War II. Aircraft were deployed at King Salmon as early as 1948 and at Galena in 1951. Due to the limitations in aircraft, personnel shortages and inadequacies in the radar detection network, the FOBs were not regularly used for interception until the mid to late 1950s, when the AC&W System became operational. Early on, between 1958 and 1961, at least 16 unsuccessful intercepts were initiated against Soviet bombers flying in the Alaskan theater (Argonne National Laboratory 2002b; Whorton, Williams, and Alpert 2001).

King Salmon Airport (undated) showing ready aircraft on the apron at the King Salmon Airport. A Combat Alert Cell can be seen in the image behind the F-15 aircraft (Source: 11 AF archives).

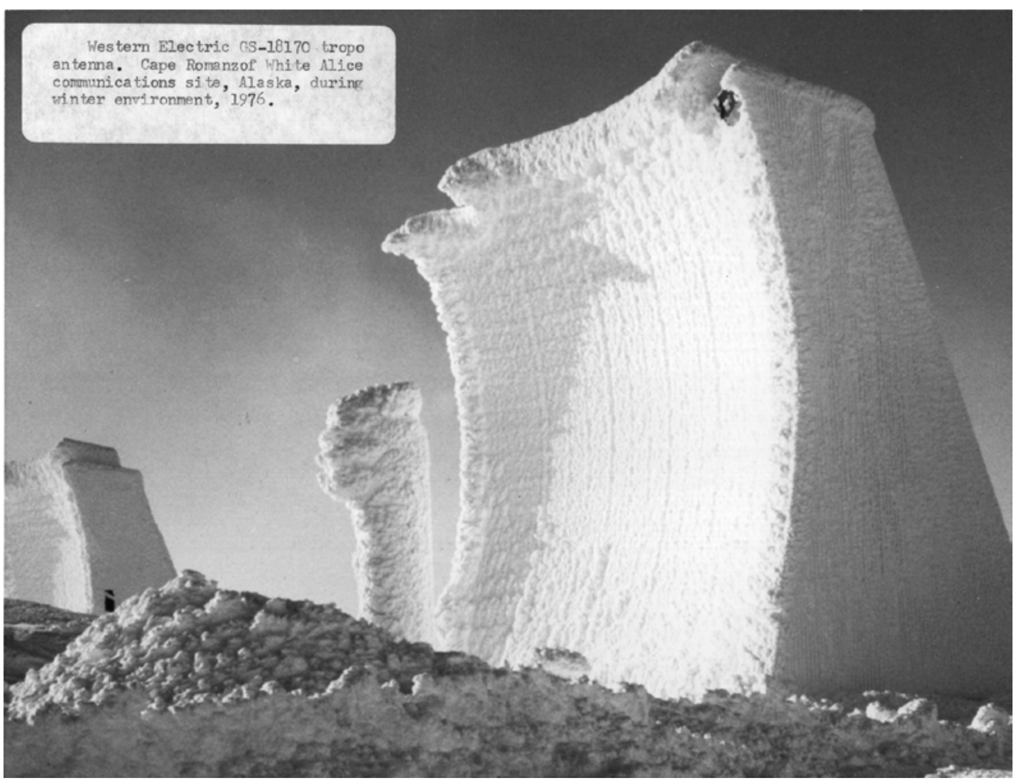
The first successful interception (i.e., interceptor aircraft were deployed and made contact with the intruding aircraft) of a Soviet aircraft, a Tu-16 bomber, over Alaska was made by a F-102 aircraft operating from Galena in December 1961. The first intercept of a Soviet bomber by a U.S. aircraft from King Salmon occurred on September 2, 1965 (Argonne

National Laboratory 2002b; Whorton, Williams, and Alpert 2001). Aircraft stationed at Alaskan FOBs intercepted more than 300 Soviet aircraft during the Cold War. (Whorton, Williams, and Alpert 2001).

2.1.8 Communication

High-frequency radio communications were initially used to link AC&W sites with FOBs, DEW Line sites, and control centers, but the system proved to be unreliable due to atmospheric disturbances and the fact that AC&W radars frequently jammed VHF signals. In December 1953, the Air Force formed the Alaska Communications Study Group to develop an effective communications system. In 1954, the Alaska Communications Study Group turned to Bell Electric Systems to recommend a new communications system for Alaska (Cloe 2008; Reynolds 1988).

Bell recommended a tropospheric scatter system supplemented with microwave radio relay sites called the WACS. The tropospheric scatter system involved bouncing ultra-high frequency (UHF) radio waves off the troposphere from a parabolic transmitting antenna and back down to a receiving antenna.to relay messages. The parabolic antennas were 60 or 120 feet in diameter and could reliably transmit messages up to 200 miles using the troposphere system. The recommendation was accepted, and in 1955, Western Electric Company, was awarded a contract to design and construct the new communications network (Cloe 2008; Reynolds 1988).



Cape Romanzof White Alice tropospheric antennas during the winter of 1976 (Source: 11 AF archives).

Initially, thirty-one WACS installations were constructed between 1955 and 1957. Twenty-two were tropo stations. Six were microwave stations and 3 were a combination of tropo and microwave stations (TD-2). When possible, WACS stations were collocated at AC&W sites to save on construction, operations, and maintenance costs. In all, fourteen of the original 31 sites were collocated at AC&W installations including Bethel, Cape Lisburne, Cape Newenham, Cape Romanzof, Fort Yukon, Indian Mountain, King Salmon, Kotzebue, Middleton Island, Northeast Cape, Sparrevohn, Tatalina, Tin City, and Unalakleet (North River) (Reynolds 1988).

The WACS construction program was expanded in the late 1950s and early 1960s to support the Ballistic Missile Early Warning System (BMEWS) and the Aleutian section of the DEW Line under Project Stretchout. By the early 1960s, there were 71 WACS sites linking AC&W and DEW Line sites into a cohesive network relaying communications (unidentified aircraft number, speed, direction, and altitude) back to Elmendorf and Eielson AFBs, the BMEWS at Clear AFB, and NORAD Headquarters in Colorado (Reynolds 1988).

White Alice dish and tropo antennas at Cape Lisburne (Source: 11 AF archives).

2.2 Aircraft Control and Warning System: 1965 To Present

Air defense systems that focused on bomber attacks, such as AC&W, declined in strategic importance during the 1960s. By 1955, the Soviet Union shifted their focus from long-range bombers to intercontinental ballistic missiles (ICBMs). After the Soviet Union launched an ICBM in 1957, the Air Force accordingly shifted to missile warning and defense, which required new technology and a system capable of detecting ICBMs. The BMEWS became operational in the early 1960s. Once the BMEWS was complete, systems designed to detect bomber attacks (such as AC&W and DEW) were relegated a more subordinate role. BMEWS provided early warning of an ICBM attack, and the others provided advanced warning of bomber attacks, which would likely follow an ICBM attack (Ray 1965).

Relatively little improvement to the AC&W System was accomplished during the 1960s. The United States was focused on the conflict in Southeast Asia, and there was a lack of funding. The only change was the installation of the Alaska-unique AN/FYQ-9 in 1965. The ANFYQ-9 was a computer-assisted radar track reporting system that provided data via leased commercial satellite communications from all 18 AC&W radar installations to the NORAD control centers and the ANR Control Center via WACS (11 AF 1982, 1996a).

In 1968, bids were solicited, from private operators, to take over WACS, and in 1969, WACS was purchased by RCA Alaska Communications, Inc. (ALASCOM). The system was used until the late 1970s, when it was deactivated and replaced by a privately owned satellite terminal communications system (Reynolds 1988).

In 1969, the Joint Chiefs of Staff directed a reduction in air defense forces, resulting in the closure of AC&W installations at Fire Island, Northeast Cape, and Unalakleet and the Aleutian Extension of the DEW Line to reduce the budget (Cloe 2008).

By the 1970s, the AC&W System was determined too expensive to maintain and was obsolete. In 1974, Air Staff released its Saber Yukon study, which recommended that the system be modernized. As a result, the United States decided to replace the existing system with an Air Force-Federal Aviation Administration (FAA) joint use Regional Operations Control Center (ROCC)/Joint Surveillance System (JSS). Once complete, ROCC would allow all data to be monitored remotely, eliminating the large numbers of personnel needed to run the site. Until ROCC was operational, the Air Force reduced costs by employing civilian contractors for operations and maintenance at remote installations, lowering the number of military personnel required to operate each of the radar installations (Cloe 2008; Denfeld 1994; 11 AF 1996a; 611 CES 1998).

In September 1983, the ROCC became fully operational, covering both Alaskan and Canadian stations. Situated at Elmendorf AFB, the central control of ROCC allowed personnel to perform air defense and tactical missions from the base. Radar data from the remote sites were transmitted via satellite to the ROCC, where personnel monitored the radar and directed intercepts of unknown aircraft. The central control allowed the total elimination of military assignments at remote installations, and by early October 1983, all military personnel were withdrawn from the installations leaving the radar installations civilian-contractor operated and maintained. In November 1983, the AAC inactivated AC&W squadrons attached to the sites and re-designated select locations as long range radar sites (LRRS) (Cloe 2008; 11 AF 1996a; 611 CES 1998).

The final step in modernizing select AC&W sites, now LRRS, occurred when the installations were upgraded with AN/FPS-117, minimally attended radars (MARs), which had both search and height finding capability. Under code name "Seek Igloo", the AAC re-equipped the majority of LRRS with MAR from 1984-1985. The newly equipped stations allowed the Air Force to cut costs by reducing the number contractor personnel necessary to operate and maintain the radars to six or fewer at each station (Denfeld 1994).

At most of the AC&W sites, the original buildings were used and maintained throughout the period of operation. New composite buildings were constructed at some of the sites (Tin City, Cape Lisburne, and Cape Newenham) in the late 1960s/early 1970s. The new composite buildings used concrete or steel-paneling rather than wood and aluminum paneling. The improved insulation of the concrete/steel provided more comfortable conditions and allowed for a myriad of living/working functions under a single roof, a solution that was responsive to the extreme climactic conditions of remote Alaskan locations. In the 1980s, four sites (Cape Romanzof, Indian Mountain, Sparrevohn, and Tatalina) received new composite buildings to house MAR facilities. The uniquely designed composite buildings consisted of two, double domes, one housing personnel and the other housing industrial operations (Cloe 2008).

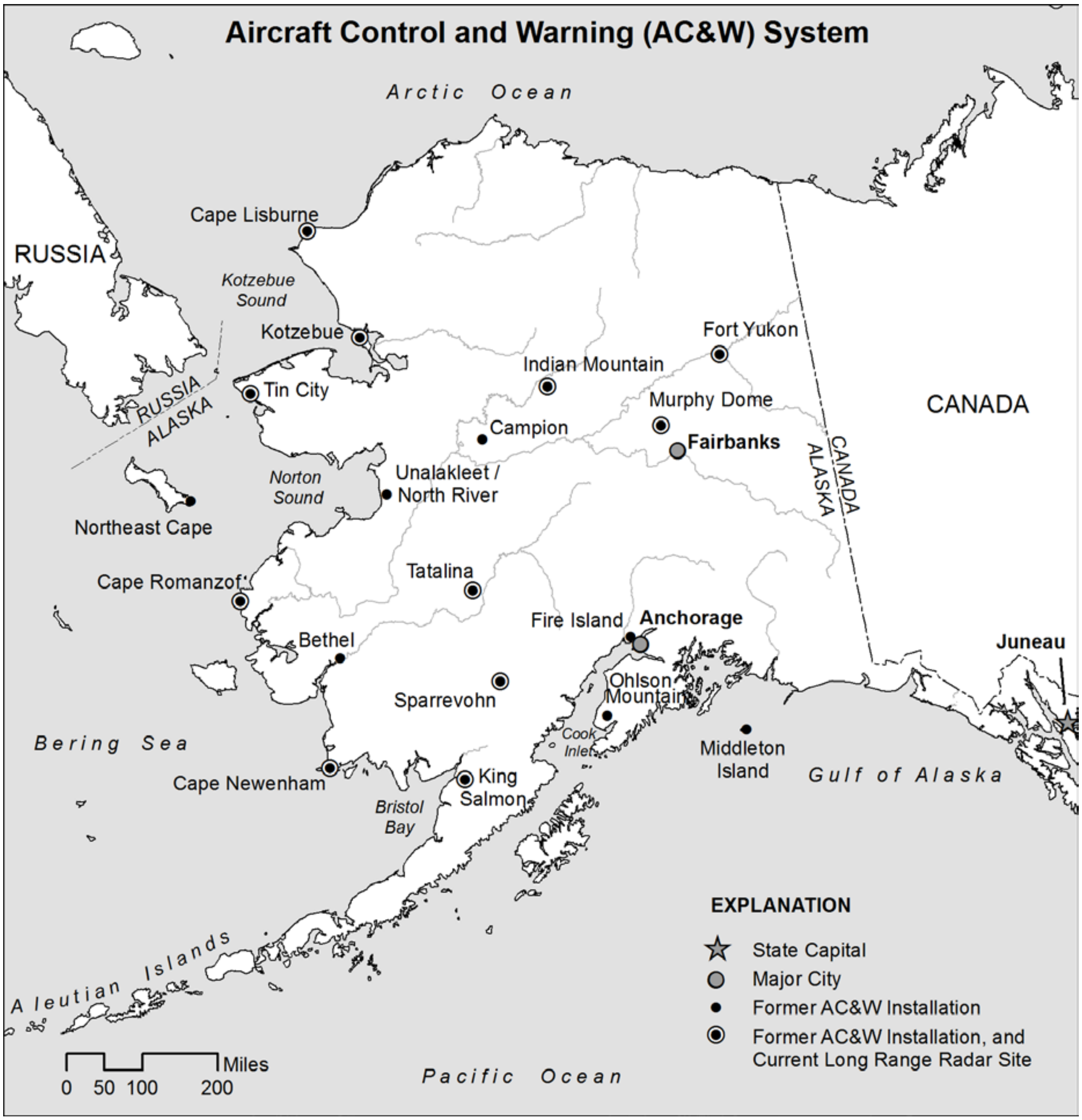
Sparrevohn Long Range Radar Site (circa 1980s) showing new, double domed composite buildings (Source: 11 AF archives).

Of the 18 original AC&W installations situated in Alaska, eleven (Cape Lisburne, Cape Newenham, Cape Romanzof, Fort Yukon, Indian Mountain, King Salmon, Kotzebue, Murphy Dome, Sparrevohn, Tatalina, and Tin City) operate as LRRS. King Salmon also functions as a FOB. Today, the remaining sites are part of the Alaska Radar System (ARS) managed by the 611th Air Support Group (611 ASG), a tenant of Joint Base Elmendorf Richardson (JBER) in Anchorage, Alaska.

Only four installations (Cape Lisburne, Fort Yukon, Kotzebue, and Tin City) retained enough historic integrity to be considered eligible for listing in the National Register of Historic Places (NRHP). However, most buildings at these installations have been demolished. The installations have also had environmental remediation projects at the sites.

3 INDIVIDUAL AIRCRAFT CONTROL AND WARNING SYSTEM SITES

This section presents brief descriptions of each of the 18 Aircraft Control and Warning (AC&W) sites in Alaska and associated operation units. The sites are presented in order of completion date.



Map showing the locations of Aircraft Control and Warning Installations. Some locations are still operational today as Long Range Radar Sites within the Alaska Radar System (Source: CEMML).

3.1 MURPHY DOME

Murphy Dome is located in the central interior of Alaska, approximately 20 miles northwest of Fairbanks at 64°57'N148°21'W (Girardin 2009). The 876- acre site occupies a bedrock hill with relatively steep slopes at a maximum elevation of 2,930 feet above mean sea level. The hill is located 6 miles northwest of Goldstream Creek and the Alaska Railroad. Treeless tundra vegetation characterizes the higher elevations where the facilities are situated, while lower slopes support a forest (birch, white spruce, and aspen) interspersed with open areas (willows, dwarf birch, alder, and grasses).

Murphy Dome AC&W Site (undated). The three radomes at Murphy Dome are shown at the top of the hill with support structures seen lower down the hill (Source: 11 AF archives).

Murphy Dome and Fire Island were the two master ground-controlled interception (GCI) radar stations constructed in the early 1950s — Murphy Dome for the northern sector and Fire Island for the southern. Two companies built the installation: Peter Kiewit and Sons and Morrison-Knudsen Construction. Because it was located approximately 25 miles west of

Fairbanks, Murphy Dome was one of the easiest stations to build. Labor disputes, however, caused some delay (AAC 1953). Work began in June 1950 and was completed in July 1951 at a total cost of $4,581,777 (611 CES 1998). The site became partially operational in September 1951 and fully operational in the spring of 1952.

The site was originally equipped with an AN/CPS-6B search and height finder radar. It received an AN/FPS-6 radar in the late 1950s (Sturm 1957; 611 CES 1998). Later, the installation was re-equipped with the AN/FPS-93A (search radar) and the AN/FPS-90 (a high-powered version of the FPS-6 height finder radar).

Initially, Murphy Dome was operated by a detachment of the 532nd Aircraft Control and Warning Group (ACWG). When the 532nd was deactivated, the 160th Air National Guard (ANG) operated the site until early 1953, when the 548th ACWG briefly took over. Later that year, with the deactivation of the ACWG, squadrons and their detachments operated directly under the 11th Division Headquarters at Ladd Air Force Base (AFB). The 744th Aircraft Control and Warning Squadron (ACWS) was activated at Murphy Dome to maintain, support, administer, and train personnel to perform the installation's air defense missions. In 1977, as part of the Air Force's move to cut costs, the number of military personnel at remote AC&W sites was reduced. The Alaska Air Command (AAC) contracted with a civilian contractor (RCA Alaska) to handle support and maintenance at the sites, including Murphy Dome. Operations positions remained with military personnel (611 CES 1998). The 744th ACWS was reassigned from Headquarters (HQ) AAC to the reactivated 531 ACWG. In 1981, the 531st was redesignated the 11th Tactical Control Group (TCG), which was redesignated the 11th Tactical Control Wing (TCW) in 1989. In July 1994, the 11 TCW was deactivated, and the 611th Air Support Group (611 ASG) assumed responsibility for all remote radar installations (11 AF/HO 1990h).

Due to its proximity to Fairbanks, Murphy Dome was resupplied exclusively by road (11 AF/HO 1990h).

Communications were initially provided by high frequency radio. When the system proved unreliable, it was replaced by the White Alice Communications System (WACS). The Murphy Dome WACS site was activated in May 1957. WACS was deactivated at Murphy Dome in May 1979 and replaced with a commercially operated and owned satellite communications system managed by RCA, Alaska Communications, Inc. (ALASCOM) (Denfeld 1994; 11 AF/HO n.d.).

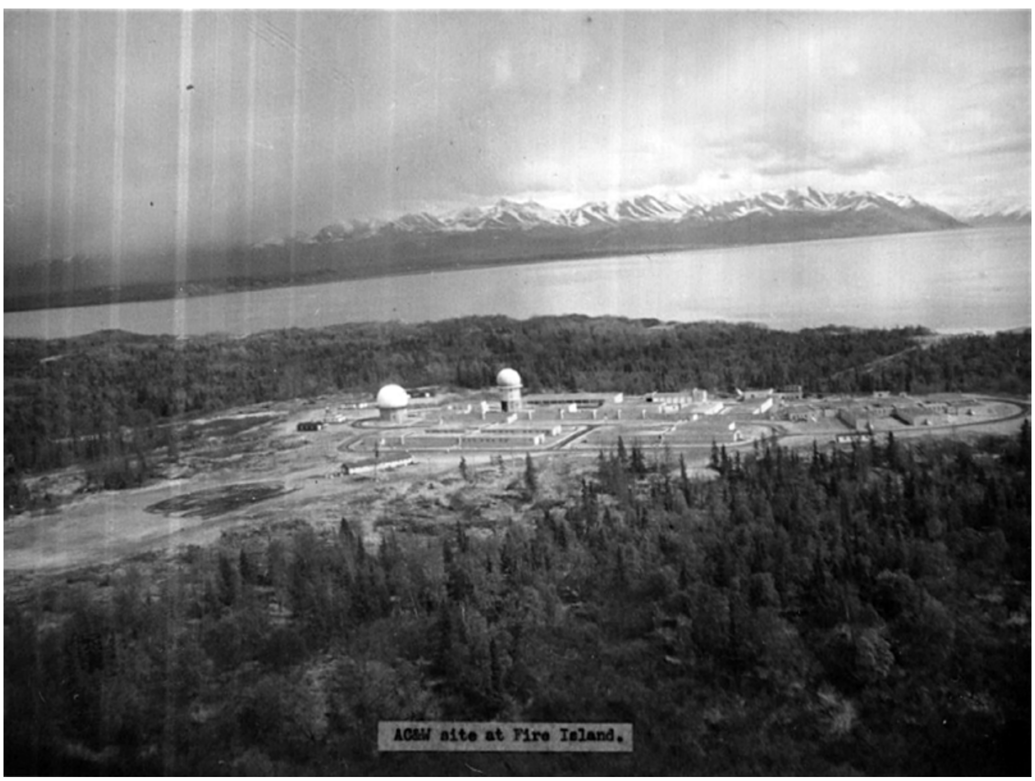
In September 1983, the Regional Operations Control Center (ROCC), situated at Elmendorf AFB, became fully operational allowing for personnel to perform air defense and tactical missions from the base and for the total elimination of military assignments at remote installations. Soon after, all military personnel were withdrawn from AC&W installations leaving the radar installations civilian-contractor operated and maintained. In addition, the AAC inactivated ACWS attached to the sites (including the 744 ACWS attached to Murphy Dome) and re-designated select locations as long range radar sites (LRRS) (Cloe 2008; 11 AF 1996a; 611 CES 1998).

As part of the Seek Igloo project, Murphy Dome was re-equipped with a Minimally Attended Radar (MAR) (AN/FPS-117), which had both search and height finding capability. It became operational in 1992. Until the upgrade was complete, the FAA assumed operations and maintenance. Once the MAR was operational (1992), Murphy Dome became civilian operated and maintained. Today, the site continues to serve as a MAR installation and is part of the Alaska Radar System (ARS). It is managed by the 611 ASG and continues to be operated and maintained by civilian contractors housed at Fairbanks.

The former AC&W site at Murphy Dome LRRS was recommended as not eligible for listing in the National Register of Historic Places (NRHP) (611 CES 1998). Most of the original AC&W buildings/structures (approximately 30) at Murphy Dome have been demolished. Three AC&W/WACS buildings remain. They include a radome tower/Federal Aviation Administration (FAA) tower (Facility Number 211), a radome tower/MAR System tower (Facility Number 214), and a communications facility (Facility Number 1001). In addition to the AC&W/WACS buildings and structures, there is one, extant MAR building located at Murphy Dome, an electric power station (Facility Number 215) (CEMML 2010).

3.2 FIRE ISLAND

Fire Island was the southern master GCI site. It is located on an island approximately 2 miles off Point Campbell in the Cook Inlet just southwest of Anchorage at 61°09'N 150°13'W. The island is approximately three miles wide and six miles long (AAC 1953; Girardin 2009).



Fire Island AC&W Site (undated). Photograph shows the radomes and various buildings in the complex (Source: 11 AF archives).

The radar site was located on the highest hill of the island. The hilltop was relatively flat and densely forested (U.S. Army Corps of Engineers 1948). Climate conditions were relatively mild, and fresh water was readily available. Strong winds and daunting tidal bores (30 feet or higher) caused some problems for travel to the installation (Pullum 1988; 626 ACW Squadron 1957). Fire Island was one of the most scenic of the AC&W locations.

The construction contract for Fire Island was awarded to Pomeroy & Company Inc., the lowest bidder. Because of labor problems, the occupancy date of September 1950 could not be met, nor could the original construction costs. Technological problems also delayed completion (AAC 1953). The installation was operational by September 1951 at a cost of $3,485,795. Fire Island's buildings conformed to the standardized design (wood framed buildings with interconnected, covered walk-ways) for such installations but differed in layout from Murphy Dome to fit the terrain (AAC 1968; Denfeld 1994).

Fire Island originated with an AN/CPS-6B radar and functioned to collect and interpret data from early warning stations, channeling this information to interceptor bases. Because the surrounding terrain caused high masking angles, the detection range of the low-sited radar was limited. An AN/FPS-8 backup search radar and an AN/CPS-4 backup height radar helped somewhat in ameliorating this problem (626 ACW Squadron 1957). The CPS-6B was later replaced with the AN/FPS-20 (626 ACW Squadron 1961).

The 626th ACWS in the 10th Air Division operated Fire Island. The site was resupplied annually during the Mona Lisa (later Cool Barge) program. Emergency supplies and fresh food were brought by air (via helicopter) from Elmendorf AFB. Because of strong winds and daunting tidal bores, most travel to the installation was by air to a landing strip on the island (AAC 1968; Pullum 1988; 626 ACW Squadron 1957).

In 1961, the site was under joint occupancy by the Air Force and the FAA. In 1969, the Air Force ceased operations at Fire Island and inactivated the 626 ACWS. The Air Force transferred the site, including all real estate property, to the FAA in 1970. The FAA departed in 1978, and the Air Force environmentally remediated the installation in 1985. The Air Force does not retain a lease on the property (Cloe 2008; Denfeld 1994; Pullum 1988).

The former AC&W site at Fire Island is not eligible for listing in the NRHP. With the exception of one building (housing water tanks), all of the original AC&W buildings/structures (approximately 30) have been demolished and the site environmentally remediated. For the most part, the island is unoccupied, although a couple of families have supported themselves with fishing over the years.

3.3 KING SALMON

King Salmon Airport (formerly Naknek Field) is located on the northern Alaska Peninsula, approximately 340 miles southwest of Anchorage, at 58°41'N 156°40'W (Girardin 2009). The installation is situated along the northern bank of the Naknek River immediately east of the village of King Salmon. The landscape is characterized by low topographic relief, with elevations ranging from 30 to 68 feet above mean sea level. Numerous ponds, lakes, wetlands, and streams are in the area. The vegetation cover is primarily grasses and shrubs, although some wooded areas are present east of the runways. The installation occupies a total area of 727 acres, which includes 4 main areas and 16 land parcels adjoining the airport and north of King Salmon village.

King Salmon AC&W Site (1956). Aerial view of the King Salmon AC&W site showing its two runways (Source: 11 AF archives).

King Salmon was originally constructed by the Civil Aeronautics Authority (CAA) in 1931, a forerunner of the FAA, and acquired by the Army in 1941 (Argonne National Laboratory 2002b; Whorton, Williams, and Alpert 2001). The Air Force began using the airfield in 1948 as a Forward Operating Base (FOB). In 1950, it became the location one of the original 12 AC&W sites and was co-located with the FOB. The United States Air Force awarded the contract to build an AC&W installation at King Salmon to Gaasland & Company in April 1950. Construction was completed a year later at a cost of $3,677,372 (611 CES 1998). King Salmon became operational as a GCI site in November 1951. Typical of other AC&W installations in Alaska, King Salmon AC&W structures consisted of the radomes, one- and two-story prefabricated buildings, and enclosed arctic walkways connecting them. In March 1953, King Salmon was converted to an air defense direction center (later a North American Air Defense Command (NORAD) Control Center) responsible for air defense in the southern sector of the Alaska NORAD region (ANR) (AAC 1968; Argonne National Laboratory 2002b; 11 AF/HO 1990f; Whorton, Williams, and Alpert 2001).

The King Salmon AC&W site was originally equipped with a AN/FPS-3 search radar and an AN/FPS-6 height finder radar, and an AN/FPS-20A became the prime search radar in 1958 (705 ACW Squadron 1958). The first observation by radar operators of a Soviet aircraft - a reconnaissance flight off Alaska's coast - occurred in March 1958 (611 CES 1998). In the mid-1960s, the AN/FPS-87A search radar (a modified FPS-20) and the AN/FPS-90 height finder radar (a modified FPS-6) were installed, as was the FYQ-9 Semiautomatic Data Processing and Display System, which eliminated the labor-intensive and time-consuming manual system of passing track data (705 ACW Squadron 1965; Girardin 2009).

Communications were originally provided by high frequency radio. When the system proved unreliable, it was replaced by WACS. The King Salmon WACS site was activated in May 1957. It was deactivated in August 1979 and replaced with a commercially operated and owned satellite communications system managed by ALASCOM (Denfeld 1994; 11 AF/HO n.d.).

King Salmon Airport (no date). Aerial view showing site layout (Source: 11 AF archives).

Initially, Detachment F-3 of the 531 ACWG staffed King Salmon. In December 1952, the 705th ACWS was activated and assigned to the 531st. The 705th continued to operate the AC&W facility through various command reassignments until 1977 when it came under contract maintenance (Girardin 2009).

King Salmon was chosen to test the new AN/FPS-117 MAR under the AACs program to modernize its ground-based radar system (Seek Igloo). Testing began in 1982, and the MAR became operational in 1983. The MAR transmitted aircraft tracking data via satellite to the ROCC at Elmendorf AFB (operational in 1983) for display on computer screens. This capability eliminated the need to station military personnel at the radar sites, and the 705 ACWS was deactivated later that year (11 AF/HO 1990f; 611 CES 1998).

King Salmon Airport was drawn down in 1994, following the end of the Cold War, with the Air Force withdrawing all permanent military personnel and aircraft from the installation. Today, the installation is part of the ARS and operates under contract personnel with the Air Force (611 ASG) serving as caretaker for certain facilities. Other installation buildings have been leased to the state of Alaska and other government agencies such as the National Park Service (NPS) and to local community organizations such as the Bristol Bay Borough. The MAR facility continues to operate (Argonne National Laboratory 2002b; Whorton, Williams, and Alpert 2001).

The King Salmon location had both an AC&W station and an FOB. The FOB was determined eligible for listing in the NRHP for its significant role in supporting the United States Cold War strategic defense mission, as well as for its role in the development and economic growth of the state of Alaska (611 CES 1999).

In December 1998, 71 buildings and structures within the King Salmon main base, Radar Approach Control (RAPCON), and marina areas of the installation were evaluated. Because the AC&W station was collocated at the FOB, some of the buildings/structures functioned as both FOB and AC&W facilities. Facilities were evaluated by individual merit and by their ability to contribute to a historic district. None of the buildings evaluated were determined eligible for individual listing on the NRHP. However, eleven of the facilities and associated interconnecting walkways were determined eligible for inclusion in the NRHP as contributors to a discontiguous historic district dating from 1948 to 1989, King Salmon's FOB period of significance. Since first recorded as a proposed district, three of the 11 contributing facilities have been demolished due to environmental restoration activities, the effects of which were mitigated in a 1998 Memorandum of Agreement (MOA) (611 ASG et al. 1998). The remaining properties include a Combat Alert Cell/Alert Hangar (Facility Number 160), a communications tower (Facility 327), an electric power station (Facility Number 335), a radome tower (Facility Number 625), a vehicle operations parking building (Facility Number 632), a vehicle maintenance shop (Facility Number 636), an electric power station (Facility Number 638), and a base engineering maintenance shop (Facility Number 642) (CEMML 2010).

In addition to the FOB/AC&W buildings and structures, there are four, extant MAR System buildings located at King Salmon. They include a radio beacon facility (Facility Number 128), a composite industrial building (Facility Number 130), a residential dome/civilian camp (Facility Number 132), the radome (Facility Number 234), and an electric power station (Facility Number 235) (CEMML 2010).

3.4 TATALINA

Tatalina is located in the southwestern interior of Alaska, about 240 miles west of Anchorage at 62°55'N 156°00'W (Girardin 2009). The nearest communities are the village of Takotna, 5 miles northwest, and the town of McGrath, which is 14 miles east of the installation. The 4,968-acre site occupies the summit and southeastern slope of Takotna Mountain, which reaches a maximum elevation of 3,203 feet above mean sea level. The installation consists of an upper camp, lower camp, a barge landing on the Kuskokwim River, and runway, interconnected by a road and, at one time, tramway (abandoned and demolished). The general area is forested except for portions of Takotna Mountain above 2,000 feet in elevation (i.e., above the tree line) (CEMML 2010).

Tatalina AC&W Site (undated). Photograph showing the top camp and the two radomes, the parabolic antenna from the White Alice Communication System (to the right), and the cable tower from the tramway (Source: 11 AF archives).

The AAC and United States Army Corps of Engineers surveyed the site in late 1949 and early 1950, determining that its elevation, freedom from obstruction, and strategic central location made the site suitable for a short-range GCI facility (611 CES 1998). Haddock Engineers, Ltd., won the contract and began construction early in 1951. Although it was operation in 1952, the installation was not complete until 1954. The total construction cost was $4,136,353. The lower camp was located on a wooded knoll between two streams at the base of Takotna Mountain. The radome was situated atop the mountain, at 3,200 feet, connected to the main camp by a 4,300-foot tramway, which was deactivated in 1959 due to accidents and unreliability. The top camp, quartering about 15 personnel, was occasionally isolated by snow and, therefore, contained emergency supplies during the winter. The original road between camps was a difficult switchback. The current road is more indirect, but easier to traverse up the mountain. The airstrip is approximately 1.5 miles southwest of the lower camp, and the barge landing is approximately 16 miles southeast at Sterling Landing (AAC 1953; AAC 1968; CEMML 2010).

Tatalina was initially manned by Detachment F-10 of the 531 ACWG. The 717th ACWS was activated in December 1952, taking over Tatalina and continuing to operate the station under various command reassignments. Gradual reduction of the site's military personnel and their replacement by contract personnel occurred from 1977 to 1985. In 1994, the 611 ASG assumed responsibility for remote radar installations (AAC 1953; AAC 1968; 11 AF/HO 1988).

Ordinarily, supplies of water and fuel were transported to Tatalina several times a week by truck (611 CES 1998). During the winter, the lower camp could be supplied only by air. The rest of the year, supplies arrived by river through the Mona Lisa, later Cool Barge, resupply operation traveling up the Kuskokwim River. Supplies were then trucked over the 16 miles between the barge landing and the camp (AAC 1953; AAC 1968; 11 AF/HO 1988). Communications were initially provided by high frequency radio. When the system proved unreliable, it was replaced by WACS. The Tatalina WACS site was activated in October 1957 and deactivated in February 1979 when it was replaced with a commercially operated and owned satellite communications system managed by ALASCOM (Denfeld 1994; 11 AF/HO n.d.).

Tatalina was originally equipped with an AN/FPS-3 search radar and an AN/FPS-6 height finder radar. In the 1960s, the installation was re-equipped with the AN/FPS-93A search and the AN/FPS-90 height finder radars. In 1965, Tatalina received the FYQ-9 data equipment. As part of the Air Force cost-reduction program beginning in 1977, military positions at Tatalina were reduced, and contracted support personnel arrived. When the ROCC became operational in 1983, Tatalina was re-designated a LRRS and began transmitting its radar data via satellite to Elmendorf AFB. Once it became a LRRS, the 717 ACWS was deactivated. In 1984-1985, contract personnel were further reduced at Tatalina when the Seek Igloo project activated the AN/FPS-117 MAR. Today, the former Tatalina AC&W site serves as a MAR installation and is part of the ARS managed by the 611 ASG (611 CES 1998).

The former AC&W site at Tatalina LRRS was recommended as not eligible for listing in the NRHP (611 CES 1998). Most of the original AC&W buildings/structures (approximately 34) were demolished in the mid-1980s. Six extant AC&W facilities remain including a gymnasium (Facility Number 3033), a water supply building (Facility Number 3065), a surface weather observation facility (Facility Number 3073), a radome tower (Facility Number 3095), the airfield (Facility Number 75339), and the road system (Facility Number 85017) (CEMML 2010).

In addition to the AC&W buildings/structures, there are four, extant MAR System buildings at Tatalina LRRS including an industrial building/maintenance shop (Facility Number 3001), a residential building/civilian camp (Facility Number 3003), an incinerator (Facility Number 3004), and a fuel pump station (Facility Number 3072) (CEMML 2010).

3.5 CAMPION

Campion Air Force Station (AFS) was originally known as Galena II due to its proximity (8 miles) to the town of Galena, which is situated on the Yukon River about 270 miles northwest of Fairbanks. The station was renamed Campion in 1954 to honor a radar observer, Lt. Allen J. Campion, who was killed in an aircraft accident at Galena on November 26, 1950 (AAC 1968; 11 AF 1990a).

Installation Sign (unknown date) commemorating Lt. Allen J. Campion (Source: 11 AF archives).

The site is in the west-central interior Alaska on the Yukon River at 64°44'N 156°55'W. The installation occupies the high floodplain of the Yukon River at an elevation of 143 feet above mean sea level. The terrain is flat, with a maximum local relief of 40 feet. The landscape surrounding the installation contains numerous lakes and marshes, with forest vegetation in better drained areas of higher elevation.

The construction contract for Campion was awarded to Morrison-Knudsen Company in May 1950 for $2,238,000. The GCI site became operational in April 1952. Campion was a single camp site (i.e., radome and housing were located in the same area). It was equipped with an

AN/FPS-3 search radar. Three years later, in 1955, an AN/FPS-8 height finder was added. In 1953, Campion was changed to an air defense direction center and back to a GCI under NORAD in 1973. In the mid-1960s, the station was upgraded with an AN/FPS-93A search and AN/FPS-90 height finder radars and the new AN/FYQ-9 data processing system (AAC 1968; Cloe 2008).

Campion AC&W Site (no date) (Source: 11 AF archives).

When high frequency radio communications proved unreliable at AC&W sites, communications were replaced by WACS. Campion was tied into the new WACS system via the Kalakaket Creek White Alice site located south of Galena in 1958. After the inactivation of WACS in 1978, as part of the military's switch to leasing commercially owned communications satellites, Campion's communications were switched to the nearby ALASCOM commercial terminal.

Campion was resupplied annually during the Mona Lisa (later Cool Barge) program. Supplies were shipped by barge to Galena via the Yukon River then trucked to Campion.

Emergency supplies and fresh food were brought by air to Galena and trucked to Campion (11 AF 1990a).

A detachment from the 532nd ACWS originally operated Campion. Shortly after, the 532nd was replaced by Detachment F-8 of the 143rd ACWS attached to the 160th ACWG, an ANG unit. The 143rd was replaced by the 142nd ACWS, also assigned to the 160th. In early 1953, the Air Force's 743rd ACWS, part of the 548th ACWG, replaced the 160th ANG unit. The 743rd operated Campion beginning with 173 authorized personnel and continued to do so, under various headquarters including the AAC, for the next three decades. Reductions in personnel occurred in the early 1970s, and in 1977, an Air Force-RCA Services site-support contract eliminated 76 military positions at Campion, the remaining positions were mostly operations personnel.

In 1983, ROCC became operational allowing for the total elimination of military personnel at remote installations. Soon after all military personnel were withdrawn leaving remote installations operated and maintained by civilian contractors. In addition, the AAC inactivated ACWS attached to remote locations (including the 743rd ACWS attached to Campion) and re-designated select locations as long range radar sites (LRRS) (Cloe 2008; 11 AF 1990a).

Campion was closed in September 1985 when the placement of a MAR (AN/FPS-117) at Galena made Campion redundant. The former AC&W site at Campion is not eligible for listing in the NRHP. All of the structures at the station were demolished, the debris was buried in several landfills, and the site was environmentally restored (11 AF 1990a; Denfeld 1994).

3.6 CAPE LISBURNE

As the northernmost AC&W installation, Cape Lisburne was located along the shore of the Chukchi Sea, about 132 miles north of the Arctic Circle at 68°52'N 166°09'W (Girardin 2009). The site is approximately 570 miles northwest of Fairbanks and situated on permafrost-covered land within the Alaska Maritime National Wildlife Refuge. The nearest community is Point Hope, 40 miles southwest.

After surveys in 1949 by the AAC and the United States Army Corps of Engineers, the AAC selected Cape Lisburne as an AC&W site for its elevation, open horizon, and strategic position as the best location for an Early Warning (EW) station in northwest Alaska. It was designed as a split station, with main base camp facilities located along a coastal strip approximately 50 feet above sea level, and the upper camp radar facilities on a hill 3,000 feet southwest of the lower camp on a mountaintop approximately 1,585 feet above sea level. In June 1950, a construction contract was awarded to Gaasland & Company, which completed both camps and a connecting aerial tramway in August 1952 at a cost of $4,468,751 (611 CES 1998). The radar installation became operational in February 1953, and enclosed arctic passageways between buildings were added in 1954. The site was designed for a workforce of 89. The 21 buildings each had a 15-year life expectancy (AAC 1968; 611 CES 1998).

In 1955, the top camp was improved to include living quarters for 12 people and an inflated radome. The inflated dome proved constantly problematic and was replaced in 1961 by a rigid radome. New composite buildings were constructed at Cape Lisburne in 1968, marking the first time steel-frame, sandwich-panel buildings were planned and built in the Arctic (611 CES 1998).

In June 1951, Detachment F-7 of the 532nd ACWG was assigned to Cape Lisburne. In December 1952, the detachment was dissolved, and the 711th ACWS took over responsibility for the installation. The 711th continued to operate Cape Lisburne under various headquarters, including the AAC, until the mid-1980s (611 CES 1998; 11 AF/HO 1990a).

During the first harsh years, supplies were air dropped at the installation. Mis-drops into the ocean put a stop to the air drops, and a runway was constructed in 1953 (expanded 3 years later). Subsequently, Cape Lisburne was resupplied on an annual basis by the sealift efforts of Mona Lisa, later Cool Barge, program until 1995 (11 AF/HO 1990a).

Cape Lisburne AC&W Site. Top Camp (1960s) (Source: 11 AF archives).

Cape Lisburne was initially equipped with an AN/FPS-3 search radar. In 1958, the AN/FPS-20A search radar (a modified FPS-3) was installed. A later modification, the AN/FPS-93A, was set up in the 1960s, and the AN/FYQ-9 data system became operational in 1965 (611 CES 1998) eliminating the need to process aircraft tracking data manually.

Communications were initially provided by high-frequency radio. WACS replaced the old system when it proved unreliable. The Cape Lisburne WACS site was activated in September 1957 and deactivated in May 1979 when WACS was replaced with a commercially operated and owned satellite communications system managed by ALASCOM (Denfeld 1994; 11 AF/HO 1990a).

Cape Lisburne AC&W Site. Top Camp Road (unknown date) (Source: 11 AF archives).

In the early 1970s the tram was decommissioned. In 1977, the AAC entered into a site support contract with RCA Services to reduce military positions at the site and cut costs. The contract eliminated 79 military positions from Cape Lisburne. The remaining positions were primarily in operations. Joint Surveillance System (JSS) equipment was installed in AC&W radars, including Cape Lisburne, by 1982. The upgrade made it possible to transmit data via satellite to the ROCC at Elmendorf. Once the ROCC became fully operational in 1983, military assignments were no longer necessary. Military personnel were withdrawn from AC&W sites leaving them under civilian-contractor care. In addition, the AAC inactivated all AC&W squadrons attached to the sites including the 711th, and Cape Lisburne was re-designated a LRRS. In July 1985, under Seek Igloo, Cape Lisburne was upgraded with a MAR. The MAR (AN/FSP-117) had both a search and height finding capability. To support the MAR mission, a new composite building was constructed and unnecessary facilities were demolished. Today, the former Cape Lisburne AC&W site serves as a MAR installation and is part of the ARS managed by the 611 ASG (Denfeld 1994; 611 CES 1998; 11 AF/HO 1990a).

Cape Lisburne AC&W Site. Bottom Camp (1981) (Source: 11 AF archives).

The former AC&W installation at Cape Lisburne was recommended as eligible for listing in the NRHP (611 CES 1998). In accordance with an MOA dated October 1997, the buildings and structures at Cape Lisburne LRRS were documented to Historic American Buildings Survey (HABS) Level 2 (611 ASG et. al. 1997; 611 CES 1998; CEMML 2010).

A good portion of the Cape Lisburne installation was demolished in 2001 and 2002 due to environmental restoration activities, the effects of which were addressed in the 1997 MOA. Currently, the extant AC&W/WACS buildings and structures at Cape Lisburne include a recreation building (Facility Number 116), a heated auto storage (Facility Number 117), an electrical switching station (Facility Number 120), a water pump station (Facility Number 130), an industrial building (Facility Number 151), a waste treatment building (Facility Number 155), a water supply tank (Facility Number 200), a radome tower (Facility Number 300), the airfield (Facility Number 75339), road system (Facility Number 85017), and gravel pads (No Facility Number). All of the extant buildings/structures are considered eligible for nomination to the NRHP.

In addition to the remaining AC&W/WACS buildings and structures, there are two, extant buildings from the MAR System, a civilian camp (Facility Number 153) and a Solid Waste Disposal Facility (Facility Number 154) (CEMML 2010).

3.7 CAPE ROMANZOF

Cape Romanzof is located on a small peninsula extending into the Bering Sea on the southwest coast of Alaska in the Yukon-Kuskokwim Delta region at 61°47'N 165°56'W (Girardin 2009). The site, about 535 miles west of Anchorage, is in the Yukon Delta National Wildlife Refuge. The nearest towns, Scammon Bay to the east and Hooper Bay to the south, are both approximately 15-20 miles away.

The 4,900-acre installation occupies the slopes of Towak Mountain along Nilumat Creek (also known as Fowler Creek) and includes an upper camp at an elevation of 2,300 feet above sea level, a lower camp at 1,500 feet above sea level, and a landing strip at an elevation of approximately 300 feet above sea level. The topography is characterized by very steep slopes, between the upper and lower camps, and gentle slopes at elevations below 1,600 feet. The general area supports tundra vegetation comprising sedges, grasses, shrubs, and lichens.

As with other remote AC&W stations, surveys of the site were conducted in 1949 by the United States Corps of Engineers and the AAC. Cape Romanzof's elevation, unobstructed horizon, and strategic westward position offered the best location for an EW site for south-central mainland Alaska. The station was designed as a split camp. Gaasland & Company received the construction contract in June 1950 and began work immediately. Despite harsh weather, such as 30 feet of snow, the installation was completed in 1952 at a cost of $4,322,751. The facility became fully operational in 1953. The upper camp, at 2,350 feet atop Towak Mountain, housed the radar and quarters for the operators. The lower camp, built in a natural bowl of an extinct volcanic crater, contained support facilities. A tramway built in 1953 connected the two camps. Before tram installation, personnel hiked to the top camp, carrying a week's worth of supplies (AAC 1968; 611 CES 1998).

Cape Romanzof was supplied annually by sea through the Mona Lisa and Cool Barge programs. A runway was added in 1953, allowing more frequent and emergency deliveries by air. Detachment F-6 of the 531st ACWG initially ran the installation but was replaced with the newly activated 795th ACWS at the end of 1952. The 795th continued to operate the station through subsequent changes in headquarters assignments, including the AAC, until the mid-1980s (611 CES 1998; 11 AF/HO 1990c).

Cape Romanzof's first radar was an AN/FPS-3. In the 1960s, it was replaced by an AN/FPS-93A (a later modification of the FPS-20). In 1965, an AN/FYQ-9 data system was installed.

In February 1958, WACS replaced high frequency radio communications at Cape Romanzof. Construction of WACS at Cape Romanzof led to the construction of a 2-mile access road connecting the base and top camps. WACS was deactivated at Cape Romanzof in May 1979 and replaced with a commercially operated and owned satellite communications system managed by ALASCOM (Denfeld 1994; 11 AF/HO 1990c).

Cape Romanzof AC&W Site. Top Camp (unknown date) (Source: 11 AF archives).

In the early 1970s, the tram was decommissioned. In 1977, the AAC entered into a site support contract with RCA Services to reduce military positions at the site and cut costs. The contract eliminated 81 military positions from Cape Romanzof. The remaining positions were primarily in operations. In 1983, the ROCC at Elmendorf AFB became fully operational. Soon after, all military personnel were withdrawn from AC&W sites, leaving the radar installations completely civilian-contractor operated and maintained. In addition, the AAC inactivated AC&W squadrons attached to the sites, including the 795 ACWS, and Cape Romanzof was redesignated a LRRS. In August 1985 under Seek Igloo, the AAC, re-equipped Cape Romanzof with a MAR (AN/FSP-117). A double-geodesic dome composite building was constructed in 1984-1985 to house remaining personnel and equipment. All other unnecessary facilities were demolished by 1988. Today, the site continues to serve as a MAR installation and is part of the ARS. It is managed by the 611 ASG and is operated and maintained by civilian contractors (11 AF/HO 1990c; 611 CES 1998).

The former AC&W site at Cape Romanzof LRRS was recommended as not eligible for listing in the NRHP (611 CES 1998). Most of the original AC&W buildings and structures have been demolished, but several structures from the 1950s are still extant including a radome tower (Facility Number 100), a pump house (Facility Number 2300), the airfield (Facility Number 75339), a vehicle fueling station (Facility Number 76200), the road system (Facility Number 85017, and an aerial tramway (Facility Number 89004). One AC&W

building remains from 1964, a base engineered covered storage (Facility Number 2217). None of the buildings are considered eligible for nomination to the NRHP (CEMML 2010).

In addition to the AC&W buildings and structures, there are seven, extant MAR System buildings/structures at Cape Romanzof LRRS including a storage facility (Facility Number 2293), an industrial building (Facility Number 2294), a solid waste disposal facility (Facility Number 2295), a water supply building/ tank (Facility Number 2400), a radio beacon facility (Facility Number 2500), a residential building/radar tower (Facility Number 2940), and a surface weather observation facility (Facility Number 4101) (CEMML 2010).

3.8 TIN CITY

Tin City is located on the western tip of the Seward Peninsula at 65°34'N 168°00'W (Girardin 2009). It is about 590 miles west-northwest of Fairbanks. Originally known as Cape Prince of Wales, it was renamed Tin City in 1957 after a nearby mining community. The village of Wales is 5 miles northwest of the station, and the Siberian coastline is approximately 50-60 miles away, making Tin City the closest installation to the Soviet Union (now Russia). The installation occupies a total area of 748 acres and is subdivided into four parcels, including the lower camp, upper camp, air strip, and (at one time) a former WACS site. The upper camp is situated on the summit of Cape Mountain at an elevation of 2,275 feet above mean sea level (Girardin 2009). The lower camp is located on the lower slopes of the mountain and the Bering Sea shore at elevations of 0 to approximately 700 feet.

Tin City AC&W Site. Lower Camp (unknown date) (Source: 11 AF archives).

Gaasland & Company was awarded the contract to construct Tin City in June 1950. Work began in September 1950 and was completed in December 1952 for approximately $4,738,946. The site, which included an upper camp and lower camp with a road and tram connecting the two, became fully operational in April 1953 (AAC 1968; 11 AF/HO 1983b; 611 CES 1998).

A detachment of the 532nd ACWG staffed the installation until mid-1951, when it was replaced by a Detachment F-4 from the 160th ACWG of the ANG. In December 1953, the 710th ACWS assumed Tin City's operation and maintenance, and continued to do so through subsequent assignments to various headquarters, including the AAC. In 1977, as part of the AACs radar support contract with RCA Services, military positions were reduced to 14 personnel, primarily operational positions (AAC 1968; 11 AF/HO 1983b).

Originally equipped with an AN/FPS-3 search radar, Tin City received an AN/FPS-93A in the 1960s. The radars scanned aircraft flying out of the Soviet fighter base at Provideniya Airfield, 150 miles from Tin City. In 1965, Tin City was equipped with the AN/FYQ-9 data system providing semiautomatic capability (11 AF/HO 1983b)

Tin City AC&W Site. Upper Camp (unknown date) (Source: 11 AF archives).

Critical cargo and perishable items were delivered to Tin City by air. Non-perishable items were delivered by barge annually through Mona Lisa, later named Cool Barge. When high frequency radio communications proved unreliable, it was replaced by WACS. The Tin City WACS was activated in February 1958. It was deactivated in February 1975 and rerouted from Anvil Mountain, near Nome, via an ALASCOM-owned microwave relay, a commercially operated and owned communications system. The Anvil Mountain WACS was inactivated in June 1980. From then on, Tin City communications were routed through the ALASCOM satellite earth terminal at Tin City (Denfeld 1994; 11 AF/HO 1983b).

In an attempt to cut costs and military positions at AC&W sites, the AAC entered into a site support contract with RCA Services. The contract eliminated 81 military positions from Tin City. The remaining positions were primarily in operations. In 1982, installation of JSS equipment was complete, enabling radar and beacon data to be transmitted via satellite to the Elmendorf ROCC. In 1983, the ROCC became fully operational and military assignments at remote installations were no longer necessary. All military personnel were withdrawn from AC&W sites, leaving the radar installations completely civilian-contractor operated and maintained. In addition, the AAC inactivated AC&W squadrons attached to the sites, including the 710 ACWS, and Tin City was redesignated a LRRS (11 AF/HO 1983b).

In September 1984, under Seek Igloo, the AAC re-equipped Tin City with a MAR (AN/FSP-117), which had both search and height finding capability. The existing composite building was modified to house equipment and personnel, and all other unnecessary facilities were demolished. Today, the former Tin City AC&W site serves as a MAR installation and is part of the ARS. It is staffed with contract personnel and managed by the 611 ASG (11 AF/HO 1983b).

The former AC&W installation at Tin City was recommended as eligible for listing in the NRHP. In accordance with a MOA dated October 1997, the buildings and structures at Tin City LRRS were documented to HABS Level 3 (611 ASG et al. 1997; 611 CES 1998).

Most of the buildings located at Tin City have been demolished due to environmental restoration activities, the effects of which were addressed in the 1997 MOA. Currently, there are seven, extant AC&W buildings and structures at Tin City LRRS. They include a storage facility (Facility Number 119), a solid waste disposal facility (Facility Number 142), an AC&W operations facility (Facility Number 150), a radome tower (Facility Number 201), the road system (Facility Number 85017), the tramway (Facility Number 89004), and airfield (Facility Number 75339). All of the extant buildings/structures are considered eligible for nomination to the NRHP.

In addition to the remaining AC&W/WACS buildings and structures, there is an extant building from the MAR System; a water supply building (Facility Number 124).

3.9 NORTHEAST CAPE

Northeast Cape is located on the northeast tip of St. Lawrence Island, in the north Bering Sea, about 120 miles southwest of Nome and 40 miles southeast of Russia’s Chukchi Peninsula. Called “The Rock,” the island’s surface consists of permafrost covered by tundra or bare rock. Its highest mountain reaches about 2,500 feet above sea level (Communications & Electronics Digest 1961:28, 29).

A contract was awarded for construction of the radar site in January 1951, with a completion date set for November 1951. However, harsh weather conditions (such as 7 feet of snow and severe winds) delayed completion. Detachment A-4 (re-designated F-9 in November 1952), of the 142nd ACWS, ANG, camped at the site late in 1951. Ice prevented planes from bringing in supplies, and Alaskan Native dog sleds were used to haul light material to the small security unit manning the site until spring 1952. Construction was completed and the site became operational in December 1952. Also in December 1952, the AAC activated the 712th ACWS at Northeast Cape (AAC 1968; Cloe 2008).

Northeast Cape AC&W Site (1963) (Source: 11 AF archives).

Northeast Cape consisted of a lower camp, at the base of a mountain, an upper camp, at the top of the mountain, a tram connecting the two, and an airstrip. In 1953, the runway was improved, with spruce trees planted along it as a partial barrier to snow and wind. The bulk of the supplies were shipped in annual during the few ice-free summer months under Mona Lisa, later Cool Barge. Air lifting of supplies was possible most times year-round as well (AAC 1968; Denfeld 1994).

Northeast Cape was initially equipped with an AN/FPS-3 search radar situated atop an 1,818-foot mountain. Like other remote AC&W sites, the base camp consisted of buildings connected by covered passageways that housed all support facilities. In February 1958, a WACS site became operational at Northeast Cape. During the 1960s, the installation received improvements in equipment of the kind installed at other remote radar sites. In 1963, the radar was re-equipped with an AN/FPS-20A (Cloe 2008; Reynolds 1988).

The site was closed in 1969 and the AAC inactivated the 712th attached to the site. The AAC transferred site responsibility to the WACS contractor. The WACS site, collocated with the AC&W site, continued operation through the early 1970s. It was deactivated in 1974 (Cloe 2008).

Northeast Cape AC&W Site. Men waiting for the tram at the top camp (unknown date) (Source: 11 AF archives).

The former AC&W site at Northeast Cape is not eligible for listing in the NRHP. All of the original AC&W buildings/structures (approximately 20) have been vandalized and/or the wood removed with some buildings reduced to only foundations (Denfeld 1994).

3.10 CAPE NEWENHAM

The Cape Newenham installation is located on a peninsula near Cape Newenham on the southwest coast of the Bering Sea at 58°37’N 162°04’W (Girardin 2009) about 460 miles southwest of Anchorage. The site is surrounded by the Togiak National Wildlife Refuge. The nearest communities are Goodnews Bay, located 17 miles northwest of the installation on the north shore of Goodnews Bay at the mouth of Goodnews River, and Platinum, located on the Bering Sea coast along the south spit of Good News bay, approximately 30 miles northeast of the installation.

The installation occupies 2,359 acres of land along a 1.25-mile corridor that extends from the north coast (Kuskokwim Bay) to the south coast (Bristol Bay) of the peninsula. The area is characterized by steep slopes and pronounced topographic relief. Elevations range from sea level to nearly 2,000 feet above mean sea level. Vegetation is predominantly wet and alpine tundra and shrub thickets comprising heaths, crowberry, mosses, and lichens. At higher elevations, including the upper camp, vegetation is very sparse. An unnamed creek that flows north into Kuskokwim Bay drains a small lake located southeast of the lower camp at an elevation of 750 feet (Hoffecker, Wescott, and Greby 2001; Woodward-Clyde 1996).

The site was surveyed by the AAC and the United States Army Corps of Engineers in 1949 and was deemed suitable as an EW site. The contracting company, Haddock Engineers, Ltd., began construction in September 1950, but because of poor weather and other difficulties, they did not complete the lower camp until 1952. The upper camp was not operational until April 1954. The total cost was $4,303,962 (AAC 1968; United States Army Corps of Engineers 1950).

Cape Newenham AC&W Site (1978) (Source 11 AF archives).

The site consisted of a lower camp of offices and dormitories and an upper camp containing radar facilities connected by a tramway. The radome was placed on a mountaintop at an elevation of 2,011 feet. The lower camp was situated at 650 feet elevation in a valley between the radome mountain and another, higher but inaccessible, mountain. (United States Army Corps of Engineers 1950).

Difficulties beset the installation during its early years. Soon after its construction in 1952, the tramway broke, dropping its car 50 feet. A new tramway, in operation 2 years later, was replaced by a new Riblett-type tramway in 1962. In 1955, two radomes were destroyed by high winds. In October 1959, a new rigid radome was installed (AAC 1968; 11 AF/HO 1990b).

Further facilities were added during the 1960s and 1970s, among which was an $11.7 million composite building constructed in 1975 at lower camp. Occupation of the building, however, was delayed for 6 years due to safety problems and design changes (11 AF/HO 1990b).

Originally, Cape Newenham was resupplied by sealift as part of the operation Mona Lisa, later named Cool Barge. In 1952, a 4000 foot runway was constructed to also deliver cargo, mail, personnel, and emergency supplies to personnel (11 AF/HO 1990b).

Communications were initially provided by high-frequency radio. When the old system proved unreliable due to atmospheric disturbance, it was replaced by WACS. The Cape Newenham WACS site was activated in December 1957 and deactivated in March 1979 when WACS was replaced with a commercially operated and owned satellite communications system managed by ALASCOM (Denfeld 1994; 11 AF/HO 1990b).

Cape Newenham was initially equipped with an AN/FPS-3 search radar. The radar was modified in the early 1960s and re-designated an AN/FPS-20, which was later modified to an AN/FPS-93A. The AN/FYQ-9 semiautomatic data system was installed in 1965 eliminating the need to process aircraft tracking data manually (11 AF/HO 1990b)

The site was initially manned by Detachment F-5 of the 531st ACWG. In 1952, the detachment was dissolved, and the 794th ACWS took over responsibility for the installation. The 794th continued to operate Cape Newenham under various headquarters, including the AAC, until the mid-1980s (11 AF/HO 1990b).

In 1977, the AAC entered into a site support contract with RCA Services to reduce military positions at the site and cut costs. The contract eliminated 80 military positions from Cape Newenham. The remaining positions were primarily in operations. JSS equipment was installed in AC&W radars, including Cape Newenham, by 1982. The upgrade made it possible to transmit data via satellite to the ROCC at Elmendorf. Once the ROCC became fully operational in 1983, military assignments were no longer necessary. Military personnel were withdrawn from AC&W sites leaving them under civilian-contractor care. In addition, the AAC inactivated all AC&W squadrons attached to the sites including the 794th, and Cape Newenham was re-designated a LRRS. In October 1984, under Seek Igloo, Cape Newenham was upgraded with a MAR (AN/FSP-117), which had both a search and height finding capability. A composite building, constructed in 1969, was modified to support the MAR mission. The tram was rebuilt in 1985. Unnecessary facilities were demolished in 1986, and the runway was improved in 1987. Today, the former Cape Newenham AC&W site serves as a MAR installation and is part of the ARS managed by the 611 ASG (Denfeld 1994; 11 AF/HO 1990b).

The former AC&W site at Cape Newenham LRRS was recommended as not eligible for listing in the NRHP (611 CES 1998). Most of the original AC&W buildings/structures have been demolished, but several structures, from the 1950s, are still extant including a surface weather observation facility (Facility Number 200), a fuel pump station (Facility Number 220), a supply and equipment warehouse (Facility Number 2166), radome tower (Facility Number 4100), the airfield (Facility Number 75339), road system (Facility Number 85017), and aerial tramway (Facility Number 89004). A WACS building, a wastewater treatment building that dates from 1972 (Facility Number 2175), is also extant. None of the buildings are considered eligible for nomination to the NRHP (CEMML 2010).

Cape Newenham AC&W Site. Top Camp (unknown date) (Source 11 AF archives).

In addition to the AC&W/WACS buildings and structures, there are three, extant buildings representing the MAR system including a surface weather observation facility (Facility Number 201), a water supply building (Facility Number 2402), and a warehouse supply and equipment building (Facility Number 2180) with a solid waste disposal facility inside (Facility Number 2181) (CEMML 2010).

3.11 INDIAN MOUNTAIN

Indian Mountain is located in west-central Alaska, about 170 miles northwest of Fairbanks, at 66°04’N 153°41’W (Girardin 2009). The nearest community, Hughes, is 18 miles east. The 4,226-acre installation includes an upper camp that occupies the summit of Indian Mountain at an elevation of 4,200 feet above mean sea level and a lower camp at the confluence of Indian River and Utopia Creek at an elevation of approximately 1,000 feet. Undisturbed areas at the upper camp support tundra vegetation consisting of sedges, low willows, cranberry, lichens, and other plants. Poplar-spruce forest, also containing aspen, birch, and willow, is found at lower elevations (Hoffecker, Wescott, and Greby 2001; Wescott et al. 2000).

Indian Mountain was one of two additional AC&W installations added to the original 10 to cover gaps in the interior. The other was Sparrevohn. Construction was undertaken by the military (807th Engineer Aviation Battalion) starting in July 1951. The site consisted of a top and bottom camp with a 10-mile road connecting the mountaintop camp with the main base camp. Indian Mountain was the only split camp AC&W installation without a tram. The GCI installation became operational in November 1953 at a cost of $1.5 million (AAC 1968; 11 AF/HO 1990e).

Indian Mountain AC&W Site (circa 1961). Lower Camp (Source: 11 AF archives).

Indian Mountain's first radar was an AN/FPS-3 search radar. In 1957, an AN/FPS-6 height finder was added. Both radars were later re-equipped with the AN/FPS-93 search and AN/FPS-90 height finder radar, which were modifications of the AN/FPS-3 and AN/FPS-6. In 1965, an AN/FYQ-9 data system was installed, which remained in use until 1982, when it was replaced by the JSS equipment for satellite transmission of data to the ROCC (11 AF/HO 1990e).

High frequency radio initially provided communications, but when proved unreliable, it was replaced by WACS. Indian Mountain was linked to the WACS from February 1958 until its deactivation in May 1979 when it was replaced with a commercially operated and owned communications system managed by ALASCOM (Denfeld 1994; 11 AF/HO 1990e)

Indian Mountain was one of two installations resupplied entirely by air. The other was Sparrevohn. The Indian Mountain airstrip has a 12 percent slope, which is the steepest of any remote site runway (11 AF/HO 1990e).

Detachment F-16 of the 143rd ACWS, 143rd ANG, ran the site until December 1952, when the 708th ACWS, assigned to the 160 ACWG took over. In 1953, the 708th was reassigned to HQ AAC and continued operating and maintaining Indian Mountain under various headquarter assignments until 1983 (AAC 1968; 11 AF/HO 1990e).

In 1977, the AAC entered into a site support contract with RCA Services to reduce military positions at the site and cut costs. The contract eliminated 103 military positions from Indian Mountain. The remaining positions were primarily in operations. Joint Surveillance System (JSS) equipment was installed in AC&W radars, including Indian Mountain in 1982. The upgrade made it possible to transmit data via satellite to the ROCC at Elmendorf. Once operational (1983), ROCC allowed all data to be monitored remotely, eliminating the large numbers of military personnel needed to run the site. Soon after, all military personnel were withdrawn from AC&W sites, leaving the radar installations completely civilian-contractor operated and maintained. In addition, the AAC deactivated AC&W squadrons attached to the sites, including the 708 ACWS, and Indian Mountain was redesignated a LRRS (Cloe 2005; 11 AF/HO 1990e; 611 CES 1998).

In October 1984, under code name “Seek Igloo”, the AAC, re-equipped Indian Mountain LRRS with a MAR (AN/FSP-117). A new double dome composite facility was constructed in 1984 to house personnel and equipment. Any unnecessary WACS/AC&W facilities were demolished in 1987. Today, the former Cape Newenham AC&W site serves as a MAR installation and is part of the ARS managed by the 611 ASG (Denfeld 1994; 611 CES 1998; 11 AF/HO 1990b).

The former AC&W site at Indian Mountain LRRS was recommended as not eligible for listing in the NRHP (611 CES 1998). Most of the original AC&W buildings at Indian Mountain LRRS have been demolished. Five structures from the 1950-60 period remain including a radio beacon facility (Facility Number 114), a waste treatment facility (Facility Number 119), a radome tower facility (Facility Number 234), the airfield (Facility Number 75339), and the road system (Facility Number 85017). Buildings from the WACS period include a vehicle operations (Facility Number 118), water supply/pump house (Facility Number 120), a Quonset storage facility (Facility Number 122), an incinerator (Facility Number 125), and a vehicle fill station (Facility Number 76200). None of the buildings are considered eligible for nomination to the NRHP (CEMML 2010).

Indian Mountain LRRS (2009). Double Geodesic Domes (Source: Metcalf 2009).

In addition to the AC&W/WACS buildings and structures, there are four, extant MAR System buildings located at Indian Mountain LRRS. They include a radio beacon facility (Facility Number 128), a composite industrial building (Facility Number 130), a residential dome/civilian camp (Facility Number 132), the radome (Facility Number 234), and an electric power station (Facility Number 235) (CEMML 2010).

3.12 SPARREVOHN

Sparrevohn is located in southwestern Alaska, 168 miles west-southwest of Anchorage at 61°07’N 155°35’W (Girardin 2009). The nearest community is Lime Village, about 18 miles northeast of the installation on the Stony River. The 1,180-acre site occupies the summit and lower southeastern slopes of a mountain that reaches a maximum elevation of 3,302 feet above mean sea level. It consisted of an upper camp and lower camp connected by road and tram and a runway. The area is drained by several small streams that empty into Hook Creek (located 2 miles southeast of the installation). Alpine tundra vegetation is present at elevations above 1,500 feet, while spruce forest is found at lower elevations (611 CES 1998; Hoffecker, Wescott, and Greby 2001).

Sparrevohn was one of two additional gap filler sites selected by the AAC in 1951. As with Indian Mountain (the other gap filler site), potential high-cost building difficulties associated with a remote location led the AAC to use military engineer construction personnel (813th

Engineering Aviation Battalion) to build the facility. Men and equipment were airlifted to the site beginning in June 1951, and the site was operational by December, providing temporary and sporadic radar coverage with a mobile AN/CPS-5 radar. When construction was completed a year later (December 1952), the AAC decided to replace the temporary facilities with permanent ones. The runway was improved, and a tramway connecting the top and bottom camps was completed in 1957 (remaining in operation until 1981). The cost of construction was $1.5 million (AAC 1968; 11 AF/HO 1990i).

Sparrevohn AC&W Site (circa 1966) Top and Bottom Camp (Source 11 AF archives).

The mobile CPS-5 radar was replaced by an AN/FPS-3 search radar in December 1953, and an AN/FPS-6 height finder was added in 1957. Both radars were later re-equipped with the AN/FPS-93 Search and AN/FPS-90 Height Finder Radar, which were modifications of the AN/FPS-3 and AN/FPS-6. Sparrevohn received the AN/FYQ-9 data system, in 1965, to provide semiautomatic capability (11 AF/HO 1990i)

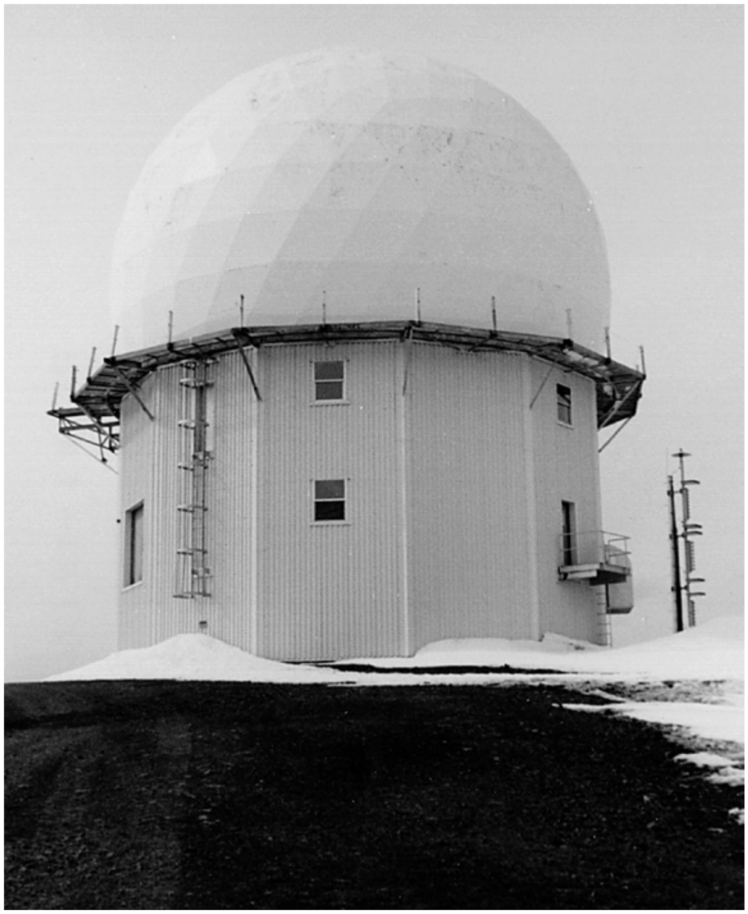
Sparrevohn was one of two installations resupplied entirely via air. The other was Indian Mountain. Communications were initially provided by high-frequency radio. When the system proved unreliable due to atmospheric interference, it was replaced by WACS. The Sparrevohn WACS site, located 1 mile south-southwest of the top camp, was activated in February 1958. The system was deactivated in May 1979 and replaced with a commercially operated and owned satellite communications system managed by ALASCOM (Denfeld 1994; 11 AF/HO 1990i).

Sparrevohn was originally operated and maintained by Detachment F-15, 626th ACWS based out of Fire Island. When the detachments were upgraded to squadrons in December 1952, the 719th ACWS, with an assigned strength of 174, operated Sparrevohn. It was assigned to the 531st ACWG and later assigned to various other headquarters including the AAC (11 AF/HO 1990i; 719 ACWS 1968, 719 ACWS n.d.).

In 1977, the AAC contracted with RCA Services for personnel to partly staff remote stations. The original staff of more than 100 personnel was reduced to 27, primarily in operations. In 1981 the tram was dismantled leaving the road as the only access between top and bottom camps. Installation of JSS equipment was completed in 1982 making it possible to transmit data via satellite to the ROCC at Elmendorf AFB. Once the ROCC went into operation (1983), military assignments at remote locations were no longer necessary. Military personnel were withdrawn from AC&W sites leaving them under civilian-contractor care. In addition, the AAC inactivated all AC&W squadrons attached to the sites, including the 719th ACWS, and Sparrevohn was re-designated a LRRS. In June 1984, under Seek Igloo, Sparrevohn was upgraded with MAR. The MAR (AN/FSP-117) had both a search and height finding capability. To support the MAR mission, a new, double geodesic dome composite facility was constructed in 1984 to house personnel and equipment. Any unnecessary WACS/AC&W facilities were demolished in 1985. Today, the former Sparrevohn AC&W site serves as a MAR installation and is part of the ARS. It is managed by the 611 ASG and operated and maintained by contract personnel (Denfeld 1994; 611 CES 1998; 11 AF/HO 1990a; 719 ACWS n.d.).

Sparrevohn LRRS (circa 1984-1984). Geodesic Dome Construction (Source 11 AF archives).

The former AC&W site at Sparrevohn LRRS was recommended as not eligible for listing in the NRHP (611 CES 1998). Most of the original AC&W buildings/structures at Sparrevohn were demolished in the mid-1980s. Six properties from the AC&W period are extant including a supply and equipment warehouse (Facility Number 130), a fuel pump station (Facility Number 140), a storage facility (Facility Number 150), a surface weather observation facility (Facility Number 165), the airfield (Facility Number 75339), and the road system (Facility Number 85017). None of the buildings/structures are considered eligible for nomination to the NRHP (CEMML 2010).



Sparrevohn LRRS. Radome – Facility 231 (unknown date) (Source 11 AF archives).

In addition to the AC&W buildings and structures, there are seven, extant MAR System buildings at Sparrevohn LRRS. MAR buildings include a water pump station (Facility Number 104), a surface weather observation facility (Facility Number 166), a radome tower (Facility Number 231), a vehicle operations facility (Facility Number 501), a civilian camp (Facility Number 502), a solid waste disposal facility (Facility Number 503), and a vehicle fueling station (Facility Number 504) (CEMML 2010).

3.13 KOTZEBUE

Kotzebue is located near the tip of Baldwin Peninsula on Kotzebue Sound, 26 miles north of the Arctic Circle, along the northwestern coast of Alaska at 66°51’N 162°35’W (Girardin 2009). The nearest community to the 676-acre site is the village of Kotzebue, which is 3 miles north of the installation. Local topography is relatively level, with some low hills that reach a maximum elevation of 155 feet above mean sea level. The vegetation is characterized by moist tundra with numerous coastal wetlands. A small unnamed lake is situated on the eastern boundary of the installation (Hoffecker, Wescott, and Greby 2001; 611 CES 1998).

In 1948, the AAC chose Kotzebue as a temporary location for an AC&W radar installation to fill a gap in radar coverage until Cape Lisburne and Tin City were completed. The temporary installation became operational in 1950, and in November 1954 the decision was made to convert Kotzebue to a permanent installation (AAC 1968; 11 AF/HO 1990g).

The construction contractor, Manson-Osberg Co. of Seattle, began work on the permanent facility in June 1955. The contract amount was $4,949,111. Numerous problems, such as labor disputes and late material deliveries, delayed completion until 1958. Designed as a single camp containing both radomes and support facilities, Kotzebue became operational as a GCI, directing fighter-interceptors from FOBs (11 AF/HO 1990g)

In 1954, Kotzebue was selected as a Tactical Air Control and Navigation (TACAN) site for airport signal transmission. The TACAN System was installed at various AC&C airports including Unalakleet, Middleton Island, Bethel, Fort Yukon, and Kotzebue. The TACAN tower remained at Kotzebue, without improvements, until being demolished in 1999 (11 AF/HO 1990g; 611 CES 1998; CEMML 2010).

Kotzebue AC&W Site. (1960s) (Source: Online Air Defense Radar Museum).

When Kotzebue became a permanent installation, its original lightweight search radar was replaced with the AN/FPS-8 search and AN/FPS-4 height finder radars. The site was upgraded with an AN/FPS-6 Height Finder Radar in 1962 and an AN/FPS-20 Search Radar in 1963. In 1965, an AN/FYQ-9 Semiautomatic Data Processing and Display System was installed to provide semiautomatic capability and eliminating the need to pass aircraft tracking data manually (11 AF/HO 1990g).

Supplies were originally air dropped at the installation. Subsequently, the installation was resupplied by sealift efforts such as Mona Lisa, later renamed Cool Barge, with personnel and perishable items, as well as critical cargo, delivered via air (11 AF/HO 1990g).

Communications were initially provided by WACS. The Kotzebue WACS site was activated in May 1957 and deactivated in May 1979 when it was replaced with a commercially operated and owned satellite communications system managed by ALASCOM (Denfeld 1994; 11 AF/HO 1990g).

The 748th ACWS was assigned responsibility for Kotzebue in 1957. Assigned, at first, to the 5060th ACWG, the squadron continued to run the installation while being subsequently assigned to various other headquarters, including the AAC (11 AF/HO 1990g).

Kotzebue AC&W Site. Old radome foundation structure (circa mid-1990s) (Source Argonne National Laboratory).

In 1977, the Air Force entered into an installation support contract with RCA Services that eliminated 69 military positions at Kotzebue. The remaining positions were in operations. In 1982, installation of JSS equipment was complete, enabling radar and beacon data to be transmitted via satellite to the Elmendorf ROCC. Once ROCC was operational (1983), military assignments at remote installations were no longer necessary. Soon after, all military personnel were withdrawn from AC&W sites, leaving the radar installations completely civilian-contractor operated and maintained. In addition, the AAC inactivated AC&W squadrons attached to the sites, including the 748 ACWS, and Kotzebue was redesignated a LRRS. In June 1984, Kotzebue LRRS was re-equipped with a MAR (AN/FSP-117), which had both search and finding capability. All unnecessary facilities were demolished in 1999. Today, the former AC&W Kotzebue site serves as a MAR installation and is part of the ARS managed by the 611 ASG. There are no active military personnel or housing at the installation. Contract personnel maintaining the installation are housed at the village of Kotzebue and work at the station in shifts. (Denfeld 1994; 611 CES 1998; AF/HO 1990g).

The former AC&W installation at Kotzebue was recommended as eligible for listing in the NRHP. In accordance with a MOA dated October 1997, the buildings and structures at Kotzebue LRRS were documented to HABS Level 3 (611 ASG et al. 1997; 611 CES 1998).

The majority of the buildings located at Kotzebue were demolished in 1999 due to environmental restoration activities, the effects of which were addressed in the 1997 MOA. Currently, there are three, extant buildings/structures from the AC&W System including a radome tower (Facility Number 203), the road system (Facility Number 85017), and the gravel pad system (No Facility Number) (CEMML 2010). The structures are considered eligible for nomination to the NRHP.

There are no extant buildings/structures from WACS or the TACAN System at Kotzebue LRRS. However, there is one extant MAR building, an electric power station (Facility Number 206).

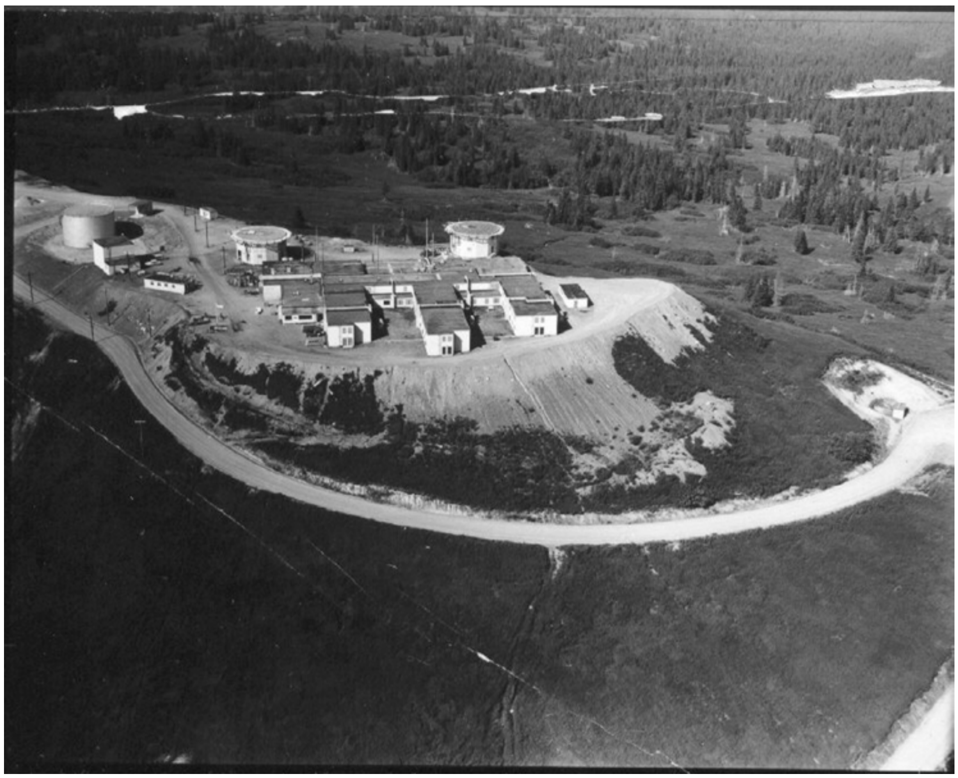
3.14 OHLSON MOUNTAIN

The Ohlson Mountain AC&W site was a 70-acre GCI installation located on the Kenai Peninsula south of Anchorage, approximately 5 miles north of Homer, Alaska. Given its proximity to Homer, it was one of two sites that could be accessed and supplied by road. Murphy Dome was the other.

Toward the last half of 1954, representatives from the AAC and the United States Army Corps of Engineers conducted a site survey of the location and determined it to be an acceptable location for a surveillance site. The contract for construction the site was awarded to Chris Berg of Seattle, Washington. Construction began in June 1955, but the site was not operational until March 1958 (Cloe 2008).

Ohlson Mountain was initially equipped with an AN/FPS-3 search radar and an AN/FPS-6 height finding radar. In 1961-62, the site was re-equipped with an AN/FPS-20A (Cloe 2008) In 1957, the AAC activated the 937th ACWS at Ohlson Mountain to carry out the facility's mission. Assigned, at first, to the 5040th ACWG, the squadron continued to run the installation while being subsequently assigned to various other headquarters, including the AAC. In 1963, the AAC determined sites guarding the southern approach to Alaska (Bethel, Middleton Island, and Ohlson Mountain) were unnecessary since an attack from the south was unlikely. The installation was decommissioned in May 1963 and the 937th ACWS attached to the site was inactivated in October 1963 (Cloe, 2001; Cloe 2008).

In December 1964, the General Services Administration (GSA) sold the Ohlson Mountain site to a private firm for $32,500.00 (Cloe 2009). Part of the facility (3.67 acres) was leased to the Defense Nuclear Agency from 1965 to 1978 (U.S. Army Corps of Engineers 1997). The site became a scientific research center, the Stanford Research Institute, conducting auroral studies. In 1985, the AC&W site was inspected and its facilities were found to be in poor condition (Denfeld 1994). The former AC&W site at Ohlson Mountain is not eligible for listing in the NRHP. The site was environmentally remediated in 2005, and there is no evidence of the site.



Ohlson Mountain AC&W Site (undated) showing the radome foundation structures without the protective domes or antennas in place (Source: 11 AF archives).

3.15 FORT YUKON

Fort Yukon is a 205 acre installation located on the Yukon Flats in northeastern Alaska at 66°33'N 145°12'W, approximately 145 miles northeast of Fairbanks (Girardin 2009). It is situated on a low terrace along the Yukon River, 430 feet above mean sea level. The landscape supports mixed forest and muskeg vegetation and is characterized by low topographic relief and numerous stream channels, sloughs, oxbow lakes, thaw lakes, and swamps. The installation is located 1 mile west of the community of Fort Yukon and is accessible by air or water only (Hoffecker, Wescott, and Greby 2001; 611 CES 1998).

As part of the plan to expand the original AC&W radar system, construction of the Fort Yukon facility began in June 1955 and was completed in February 1958 by the Manson-Osberg Construction Company for $5,068,139. It became an operational GCI installation in

April 1958. Controllers at Fort Yukon could direct fighter-interceptors from Galena, King Salmon, Elmendorf, and Eielson (11 AF/HO 1990d).

The installation was initially equipped with the AN/FPS-3 search and the AN/FPS-6 height finding radars. Later, in the 1970s, the radars were modified to the AN/FPS-93 search and AN/FPS-90 height finder radars. An AN/FYQ-9 semiautomatic data system went into operation in 1965 (11 AF/HO 1990d; 611 CES 1998).

Fort Yukon AC&W Site (unknown date). Gate entrance (Source: 11 AF archives)

Supplies were originally delivered annually via Mona Lisa, later named Cool Barge. Today, personnel and perishable items, as well as critical cargo, are delivered via air and non-perishables are delivered during the summer via barge (11 AF/HO 1990d).

Communications were initially provided by WACS. The Fort Yukon WACS site was activated in November 1957 and deactivated in July 1980 when it was replaced with a commercially operated and owned satellite communications system managed by ALASCOM (Denfeld 1994; 11 AF/HO 1990d).

The 709th ACWS was activated in January 1957 to operate and maintain the installation. The squadron was originally assigned to the 11th AF Division and reassigned to the 531st ACWG in 1977. The squadron continued to run the installation while being subsequently assigned to various other headquarters, including the AAC (11 AF/HO 1990d).

In 1977, the AAC contracted with RCA Services to partly staff remote stations. As a result, approximately 69 military positions were eliminated from Fort Yukon. The remaining positions were primarily operational. Installation of JSS equipment was completed in 1982 making it possible to transmit data via satellite to the ROCC at Elmendorf AFB. Once the ROCC was operational in 1983, military assignments at remote locations were no longer necessary. Military personnel were withdrawn from AC&W sites leaving them under civilian-contractor care. In addition, the AAC inactivated all AC&W squadrons attached to the sites, including the 709th ACWS, and Fort Yukon was re-designated a LRRS. In August 1984, under Seek Igloo, Fort Yukon was upgraded with a MAR. The MAR (AN/FSP-117) had both a search and height finding capability. To support the MAR mission, a new, 7.9 million composite facility was constructed by Chris Berg and Company to house personnel and equipment. Any unnecessary facilities were demolished. Today, the former Fort Yukon AC&W site serves as a MAR installation and is part of the ARS managed by the 611 ASG (Denfeld 1994; 611 CES 1998; 11 AF/HO 1990d).

Fort Yukon AC&W Site (circa 1956). Construction of Officers Quarters showing how early buildings were wood and one or two stories high (Source: 11 AF archives).

The former AC&W installation at Fort Yukon was recommended as eligible for listing in the NRHP (611 CES 1998). In accordance with a MOA dated October 1997, the buildings and structures at Fort Yukon LRRS were documented to HABS Level 3 (611 ASG et al. 1997; 611 CES 1998).

A good portion of the Fort Yukon installation was demolished in 1999, the effects of which were addressed in the 1997 MOA. Currently, there are five extant AC&W buildings and structures at Fort Yukon LRRS including a water supply building (Facility Number 100), a water pump station (Facility Number 102), a radome tower (Facility Number 106), a gymnasium (Facility Number 114), and the road system (Facility Number 85017). Facility

112 (warehouse) and the surrounding land were transferred to the City of Fort Yukon and are no longer within the installation boundary. All of the extant AC&W buildings/structures are considered eligible for nomination to the NRHP.

Fort Yukon AC&W Site (undated) Overview. (Source: 11 AF archives).

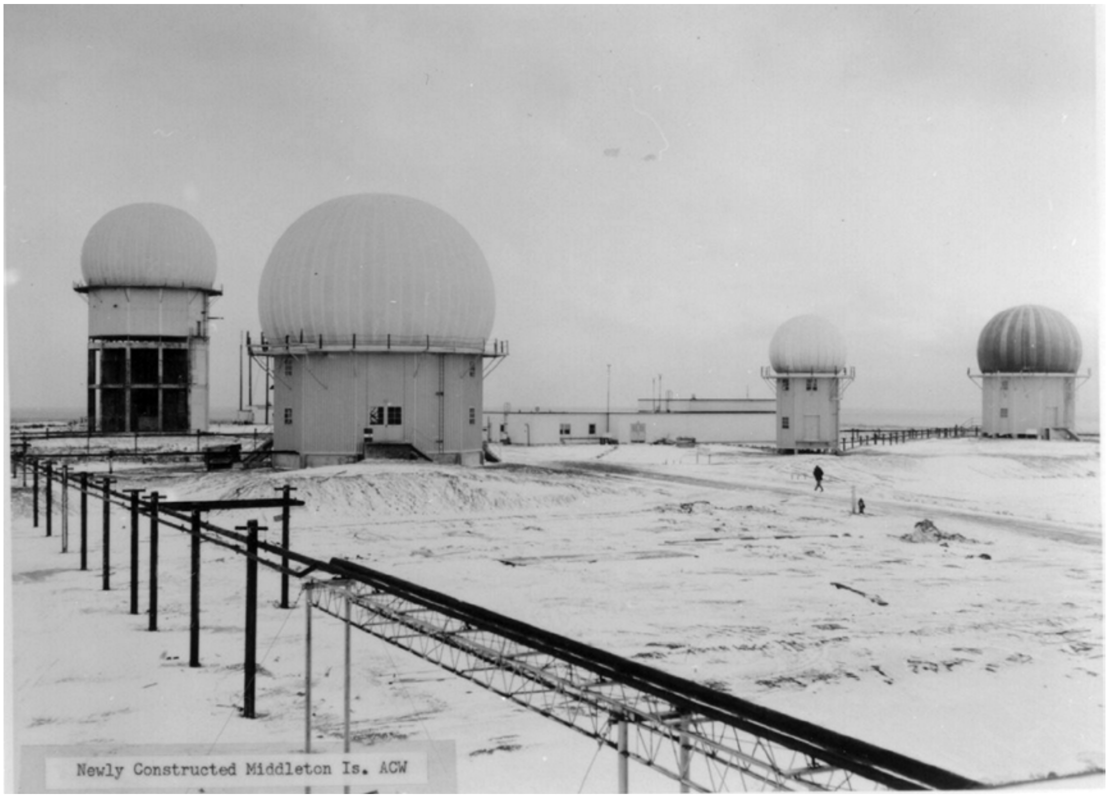
In addition to the AC&W buildings and structures, there are four, extant MAR System buildings located at Fort Yukon LRRS. They include the radome (Facility Number 106), an incinerator (Facility Number 119), a civilian camp/residential building (Facility Number 120), and an electrical power station (Facility Number 121) (CEMML 2010).

3.16 MIDDLETON ISLAND

Middleton Island is located in an area rich with seabirds and other wildlife along the Gulf of Alaska, 65 miles southwest of Cape St. Elias. The island measures 3.5 miles long by .5 mile wide. It is fairly flat with its greatest elevation being approximately 120 feet.

The Army Corps of Engineers surveyed the site for a permanent radar facility in 1948 (U.S. Army Corps of Engineers 1948:1). It was chosen in 1955 to be a GCI in the AACs extension of the permanent AC&W system and was collocated with a WACS facility. AC&W and WACS facilities were constructed by the Morrison-Knudsen Company. Construction began in 1955, with the WACS facility in operation in November 1956 and the AC&W installation operational in May 1958 (Cloe 2008; Reynolds 1988).

The site was supplied annually by Mona Lisa, later Cool Barge. Perishables and personnel were flown in. The installation had a 5,000 foot runway (Cloe 2008).



Middleton Island AC&W Site (late 1950s - early 1960s). (Source: 11 AF archives).

Middleton Island was initially equipped with an AN/FPS-3 search radar and an AN/FPS-6 height finding radar. In 1961-62, the site was re-equipped with an AN/FPS-20A (Cloe 2008).

In 1955, the AAC activated the 720th ACWS at Middleton Island to carry out the facility's mission. Assigned, at first, to the 5040th ACWG, the squadron continued to run the installation while being subsequently assigned to various other headquarters, including the AAC. In 1963, the AAC determined Middleton Island redundant. The installation was decommissioned in May 1963 and the 720th ACWS attached to the site was inactivated in October 1963 (Cloe 2001; Cloe 2008; Denfeld 1994).

Middleton Island was removed from the Air Force real estate inventory in October 1966. In November 1977, GSA sold 182 acres of land on Middleton Island to a private group of lawyers, MIDICO. The FAA acquired the balance (Cloe 2008; Reynolds 1988).

In 1985, the AC&W site was inspected, and its facilities were found to be in fair condition (Denfeld 1994). Today, the structures are in poor conditions and are used by the thousands of sea birds who inhabit the island. The FAA and its facilities remain on the island.

3.17 UNALAKLEET

Unalakleet is located on the Norton Sound of the Bering coast about 395 miles northwest of Anchorage, Alaska and 148 miles southeast of Nome. The nearby community of Unalakleet is an Alaskan Native settlement with a population of approximately 700 (State of Alaska, Department of Commerce, Community, and Economic Development 2011).

The AAC and Army Corps of Engineers surveyed the site for a permanent radar facility in 1948 (Cloe 2008). In 1955, the construction contract for Unalakleet was awarded to Sam Bergstrom of Tacoma, Washington. Unalakleet became an operation GCI station in June 1958. Communications were provided by WACS, operational in 1957, and supplies were delivered annually by barge (Mona Lisa, later Cool Barge) with perishable items and personnel flown in (AAC 1968; Cloe 2008).

Unalakleet was initially equipped with an AN/FPS-8 search radar and an AN/FPS-4 height finding radar. In late 1962, the site was re-equipped with an AN/FPS-20A (Cloe 2008).

Unalakleet AC&W Site (1967-68). (Source: Online Air Defense Radar Museum).

In April 1957, the AAC activated the 718th ACWS at Unalakleet to carry out the facility’s mission. Although assigned to various headquarters, including the AAC, the squadron continued to run the installation throughout its existence. In June 1969, the AAC ceased defense operations at the installation, and the 718th ACWS attached to the site was inactivated in October 1969. In 1971, the AAC activated the Unalakleet Recreational Annex, but it became an economic drain and was disposed of in November 1974. The facilities were demolished and the site environmentally restored in the late 1980s/early 1990s (718 ACSW 1963; Cloe 2008; Denfeld 1994).

3.18 BETHEL

Bethel is located in southwestern Alaska, about 4 miles west of the town of Bethel and the Kuskokwim River, at 60°47'N 161°53'W. The installation occupies an area of relatively low relief approximately 170 feet above mean sea level. The vegetation cover consists of sedges, sphagnum moss, willow, and alder thickets. A small pond (50 feet in diameter), two streams, and several wetlands are present.

Morrison-Knudsen Company was awarded the contract to construct for Bethel in 1955. The 14.7-acre GCI installation became operational in June 1958. A WACS was collocated at the site. It was constructed in 1957 and operational in January 1958. The WACS site was deactivated in 1979 (Cloe 2008; Reynolds 1988).

Bethel was originally equipped with an AN/FPS-8 search radar and an AN/FPS-4 height finding radar. In 1961, the site was re-equipped with an AN/FPS-20A (Cloe 2008).

In February 1957, the AAC activated the 713th ACWS at Bethel to operate and maintain the installation. Although assigned to various headquarters, including the AAC, the squadron continued to run the installation throughout its existence. In May 1963, the AAC decommissioned the Bethel AC&W site, and the 713th ACWS attached to the site was inactivated in October 1963. By December 1964, the Air Force had removed all equipment from the site and re-designated it Bethel Radio Relay Site. A single WACS array was still present in 2002, but all other facilities had been demolished (Cloe 2001; Cloe 2008).

Bethel AC&W Site (1962-63). (Source: Online Air Defense Radar Museum).

4 AIRCRAFT CONTROL AND WARNING SYSTEM REMBRANCES

The personnel who served at the Aircraft Control and Warning (AC&W) installations during the Cold War era often needed to adapt to extremes of weather, remoteness, and isolation while performing their military missions. The natural and artificial characteristics of the locations directly affected morale and operations, which were constantly tested because of site conditions. The servicemen's experiences of working and living for a year or more at one of these sites constitute a significant primary source of the history of the AC&W operations and installations, as do personal accounts of any historic place, time, or event. This section provides an overview of accounts by men who served at these remote locations. It is derived from two types of primary source material: questionnaire responses provided by veterans of AC&W installations and the AC&W squadrons' quarterly (later biannual) historic data reports. Biographical information concerning the personnel who responded to the questionnaire is provided in Appendix B.

4.1 Geographic Influences

Geography formed the initial and (with weather) the ultimate framework for how Air Force personnel described and evaluated the overall conditions of AC&W installations. Expressions ranged from descriptions of utterly bleak landscapes to awe-inspiring scenic views. Naturally, variations in location contributed to the perceptions, especially between coastal and inland sites.

Coastal sites tended to be not as spectacular as some of the inland sites, but they possessed their own form of Alaskan wilderness, with considerable contrasts. A description of Middleton Island evoked its lack of remarkable features. "Sea beaches surround the land and high, wave-cut bluffs are prominent. . . . Noticeable features are the treeless tundra [surprising for the south coast] and a series of terraces . . . [topped] . . . with peat. . . . This results in poor natural drainage so that swampy areas exist. . . . The major portion of the island is covered with grass" (Owens 1948:2).

Fire Island, on the other hand, was surrounded by quite dramatic natural features. The "surrounding mountainous terrain caused high masking angles" which imposed extreme limits on the island's low-sited radar (626 ACW 1957). "Treacherous mud flats bracket the island on two sides . . . . [and] silty grains turn into quicksand under the vibrations of a foot or tire" (Pullum 1988:H-3). "Despite deep water on the north and west sides, strong winds regularly batter the island, and ferocious bore tides smash past every day." A local fisherman commented: "I seen big ships flounder out there, when the bores start rolling off the flats. A 30-foot bore throws rocks 40, 50 feet in the air. Scares you to stand and look at it" (Pullum 1988).

King Salmon was located on the Naknek River near its estuary. "The area was fairly flat" (Houck 1999:3), which served the purpose of a multi-unit site including a Forward Operation Base (FOB) for fighter-interceptors. In contrast to King Salmon's flatness, the

Cape Newenham radar station was situated in a very unusual and starkly dramatic area. According to Master Sergeant James Brown, Jr., he was told that the "site was located in the mouth of an extinct volcano [which] accounted for the bowl shape of the area. . . . The "landscape was rough, mountainous, very rocky," and overlooking a bay (Brown 1999:3). Airman Thomas Wikoff wrote that "I can't imagine a place more desolate. There were no trees. Only tundra and rock. The airstrip [of crushed rock] was adapted to the topography, i.e., it sloped uphill (for landing) and downhill (for takeoffs, obviously). . . . 'Jagged Mountain' [was] a reminder of just how stark the landscape was in this part of Alaska" (Wikoff 1999:3).

Service men working in the 718th AC&W Squadron. The 718th squadron was assigned to the Unalakleet AC&W Site (Source: A. Biron).

Mountains and sea, as well as barren vegetation (tree line was either farther south or of low elevation due to the latitude), were typical for AC&W installations sited along the western coast. Unalakleet "was surrounded on three sides . . . by mountains and on the west by water (Norton Sound)" (Greenleaf 1999:2). "The landscape was pretty barren with trees only down in the valleys next to the river" (Prew 1999:2). Cape Lisburne was "BLEAK! No trees . . . . We were on a narrow strip of land between the Chuckchee Sea and the Ridge that the Radar was located on" (Gwizdak 1999:2). The Northeast Cape site, on St. Lawrence Island in the Bering Sea, was located "at the base of a line of mountains . . . with the sea only a short distance away" (Mitchell 1999:3). Tin City, at Cape Prince of Wales overlooking the Bering Strait, also lacked trees (being north of the tree line), its sole vegetation consisting of some summertime tundra. Otherwise, the landscape was "one of total desolation" and new arrivals were described as being "usually in varying degrees of shock when disembarking at our air strip" (Galvin 2000:2).

There was more geographical variety — and appreciation of it — with the inland AC&W installations. At Sparrevohn, more than 160 miles west of Anchorage, the landscape was described as "literally wild. . . mountains, woods and tundra" (Sunder 1999:3). Murphy Dome was only 25 miles west of Fairbanks and amidst some of Alaska's most emblematic scenery. At an elevation of 2,900 feet (most radar facilities were situated on the available high and/or open ground), it was above the tree line and ". . .had a spectacular 360 degree view of the surrounding valleys and mountains . . . including Mt. McKinley which was located 110 miles to the south" (Carolin 1999:21; Brand 1999:2). From Murphy Dome, recalled Airman Henry Brand, one had a "commanding view of [the] region [of] Fairbanks – Brooks Range - Alaska Range - Mt. McKinley."

At sites remote from not only population centers but also from highways, installations were constructed near navigable rivers, if possible, for the annual supply barges. Tatalina has "beautiful mountains all around, with one dirt road to Sterling Landing on the Kuskokwim River where they brought in fuel . . . and . . . equipment" (Breedlove 1999:3). The landscape around Campion consisted of "rolling hills" with "mountains located 100 miles north" (Corral 1999:2). Although it was 8 miles by dirt road (downhill) to Galena's Air Force Station, "the Yukon River was only about a half mile away," serving both facilities (Owen 1999:2). The Indian Mountain installation was above the Indian River, but the facility was "accessible only by air," with 3,500 feet separating the support base camp and the radar operations top camp. "The USAF had leveled just enough of Indian Mtn. to put a radar site on the peak" (Green 1999:2). Fort Yukon was located on the Yukon River on a broad alluvial plain. In First Sergeant Deit's words, "The Yukon Flats were rather drab when considered singularly, but took on a strange tranquil atmosphere during winter months and were extremely beautiful in the summer when traveling either up or down the rivers." (Deits 1999:2). The description sums the contrasting reactions to much of Alaska's wilderness.

Another aspect of the scenery that was unique to far north locations was meteorological; the aurora borealis. Staff Sergeant Frankenberg recalled a particularly memorable encounter during a return trip at night from Eielson Air Force Base (AFB) to Murphy Dome. The light of their truck lit up "an entire ten acre meadow coated with undisturbed, large ice crystals deposited on a deep bed of snow. The undulating, multicolored light from the Aurora Borealis cause the ice crystal field to change colors in concert. . . . It was so stunning [we stopped and] must have stared at it for 2 or 3 minutes without saying a word" (Frankenberg 2000: 4).

4.2 Weather

In addition to the vast wilderness, another salient feature of Alaska is its extreme climate. Because the AC&W stations were located throughout Alaska, servicemen experienced varied weather conditions. Wind dominated the coastal areas, especially on the Bering and Chuckchi Seas, whereas heavier snowfalls and lower temperatures usually occurred in the interior, along with winds at the top camps. Severity of winter conditions usually decreased along the southern coast.

Severe weather conditions at Tatalina AC&W Site, circa 1950s (Source: 11 AF archives).

Temperatures at interior sites had the greatest range: At Sparrevohn, during 1955, the "minimum temp was 59 degrees below zero. The maximum was in the 70's" (Sunder 1999:3). Between September 1963 and September 1964, Murphy Dome's temperature extremes were -30 to the "low 80s" (Sunder 1999:2); Campion, 1963, from -58° to +85° (Owen 1999:2); and Fort Yukon held "the record for both the hottest and coldest temperatures recorded in a single year in Alaska," -78° F in the winter and up to 100°F in the summer.

Some of the coastal sites could also experience extremes in temperature. Although King Salmon was located on the Aleutian Peninsula, Alaska's "Banana Belt" with a relatively mild climate (Lowe 1999:3), Staff Sergeant Larry Houck reported "a day that there was a 100° F change in temperature . . . [starting with a wind] chill factor of -80° F . . . [and] within 24 hours it stopped blowing and warmed up to 20° F . . . ." (Houck 1999:3). At Unalakleet, on the Bering Sea, it could dip "to -50° F and wind up to 70 knots (dangerous conditions)" (Prew 1999:2). Master Sergeant Thomas Gwizdak recalled a 32° F July 4th in 1973 at Cape Lisburne (Gwlizdak 1999:3).

At Tin City, winter started in September and "goes downhill from there" until the mid-winter months "when sunlight becomes almost nonexistent and temperatures fall in the -20° F to -40° F range." In those conditions, the "winds are the real killers" and "wind chills of -100° F were not uncommon" (Galvin 2000:4). Extreme cold also affected the facilities and equipment. For example, at Tin City, vehicles required antifreeze "to be added to the fuel, otherwise the gasoline would turn to slush and in extreme cases freeze" (Galvin 2000:3). In contrast to such extremes, Northeast Cape's temperatures were modulated by the surrounding sea. The range in 1968 was -10° to 10° in winter and 65° in summer. Middleton Island's climate was "mild, there being only 15 days per year during which the temperature does not rise above freezing. . . Special precautions against severe cold are unnecessary" (Owens 1948:2).

At many installations, especially on the coast, the most palpable element (and enemy) was the strong wind. Not only did it create dangerous conditions for aircraft landing and takeoff and damage to facilities, it also worsened snowfall (e.g., drifts and white-outs) and lowered temperatures (wind chill). In addition, it could delay the delivery of supplies and mail.

At Camp Lisburne, on the Chuckchi Sea, winds were reported as blowing "in from all points of the compass and intensified their [fury] with gusts reaching 125 miles per hour" (142 ACW Squadron 1952). Officer's meeting minutes at Tin City during January 1959 recorded that "although the new tramway [to the upper radar camp] is designed for operations in winds up to eighty knots, gusting winds of forty knots or over render it unsafe . . . [because those winds can] cause such severe oscillation of the cables, that on several occasions the traction and return cables have crossed. . . ." The minutes also reported radar outages totaling almost 14 hours because of extremely high winds causing excessive dimpling of radome," which would interfere with the antenna's movement. During a violent storm at Tin City, the "last recorded wind speed was a gust of 200 knots [230 mph], before the wind gauge blew away. Shortly later the radome and radar antenna tore loose and the wreckage [was] strewn out onto the ice in the Bering Sea" (Galvin 2000:3).

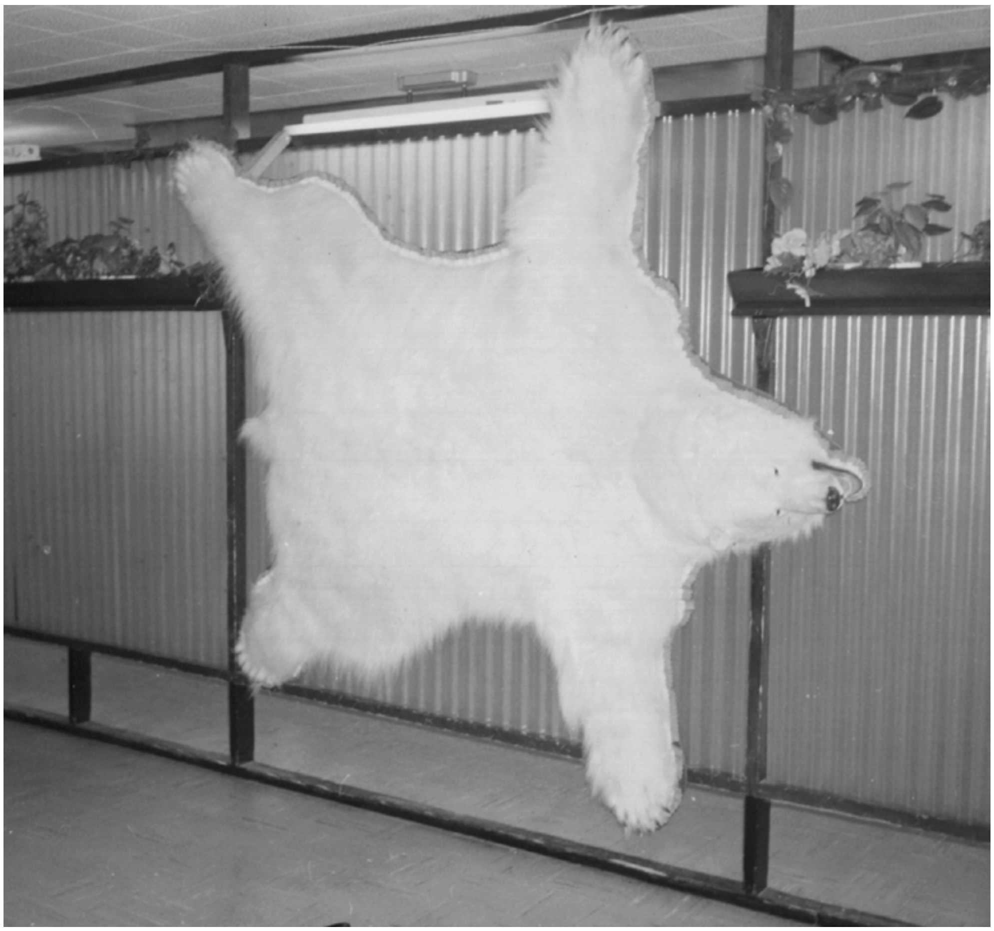
In addition to the wind, snow was the other predominant experience in Alaska. According to Airman Robert Prew (Unalakleet): "The snow drifted to the building tops and we constantly had to shovel out from the doorways. We finally covered the shoveled area with some plywood and let the snow drift over the top creating a tunnel. . . . Then we only had to keep the tunnel opening clear. We had ropes about waist high . . . running from the maintenance shop door out to each tower. This allowed us to hang on and to find our way back and forth in the blizzard conditions. . . . As the wind speed picked up we would turn on extra blowers in the towers to keep the radomes inflated — when it got to a certain level we would have to stop the antenna rotation so it wouldn't snag the radome when it got blown inward by the wind."

Airman Thomas Wikoff remembers that at Cape Newenham, the "road to the White Alice communications facility was lined with barrels with long poles to indicate where the road was during deep snow."

The air strip at Tin City was an example of how the local conditions could impact, at times fatally, accessibility to a site. As First Lieutenant Galvin recalled: the air strip "consisted of a weather shack and a 4700 foot gravel runway. . . . During the winter time keeping the road [from base camp to the] runway open was almost next to impossible. . . . There were no navigation aids to support the runway. . . . The approach . . . was dictated [by] prevailing winds . . . from the south over the Bering Sea. This was very treacherous, as the end of the runway dropped straight down 150 feet to the Bering Sea. The resulting down draft was terrific. . . . In 1957 it caused a two engine C-45 to crash into the side of the cliff killing both pilot and copilot" (Galvin 2000:3).

4.3 Wildlife

Wildlife is abundant in Alaska. Because of the remoteness of the AC&W stations, human-wildlife encounters were common.



A bear skin rug on display in an AC&W Dining Hall (Unknown location, date, and source).

Out on Northeast Cape (St. Lawrence Island), bears required special precautions. "We could not go outside," Airman James Mitchell recalled," "without a weapon due to bears of various types. I remember seeing polar bears at our disposal area." Bears also provided some remarkable incidents. Staff Sergeant Brian Coy (1999) related that "there were a lot of bears around Murphy [Dome]. They learned to open the doors in the connecting corridors and get inside. It was not unusual to see one wandering down the hallway. We lured the cubs into the NCO [noncommissoned officer] Club with fruit and candy, and fed them beer from a canteen cup. This was reasonably safe so long as you did not get between Momma Bear and her cubs. . . One of the White Alice civilian techs decided he was going to kill a bear with a Bowie knife. He found a bear, but when he made a pass at it with the knife the bear deflected it and the guy stabbed himself in the leg. We had to evacuate him to Ft. Wainwright."

At the other extreme, in size, at least, were the mosquitoes. Minnesotan Charles Sunder, an Airman (Communications) at Sparrevohn, recounted that the "summer brought mosquitoes that made the mosquitoes in Minnesota look like rookies (Sunder 1999)." Another veteran observed: "the mosquitoes were horrendous" (Cantor 1999:3).

Hunting and fishing were common outdoor activities at many AC&W installations, especially during the warmer months.

Salmon fishing at Unalakleet AC&W Site, unknown date (Source: D. Halstead).

4.4 Local People

The installations were frequently sited near local communities, which often provided the only human contact and civilized recreation off the facility. First Sergeant Charles Deits gave this account of Fort Yukon: "The village of Ft. Yukon was inhabited primarily by Athabascan Indians and was fairly modern compared to some of the interior villages. There was an excellent K thru 12 school administered by the Bureau of Indian Affairs, a couple of stores, 1 restaurant, 1 Post Office, a small medical clinic, an NCC store, an FAA station, and the airfield. There were a few Caucasians in the village. . . (Deits 1999)."

From Unalakleet, "daily runs were made to the Post Office [in the native village] for mail pick-up and to meet incoming personnel at the airstrip. The village had a population of approximately 300 native peoples . . .a Trading Post, a church mission . . ." (Greenleaf 1999:2). "A gravel road," recalled Airman David Tepe who was also stationed at Unalakleet, "led to the village" which "was mostly shacks constructed from discarded packing crates and pallets and other material obtained from the military site. The natives were very adept at shooting seals which inhabited the bay."

When possible, base personnel would socialize with local inhabitants. Airman 2C Biron recalled a New Year celebration in 1959 at Middleton Island, "when the townspeople of Cordova invited those GIs who could get off duty" to their town for a "New Year's dance" (Biron 2000:5). At Murphy Dome, Staff Sergeant Frankenberg recounted how he and a friend "helped a local resident put a Chevy V8 in his Jeep. For this, he gave us a tenderloin of a moose he shot. We made a pit barbeque and put together a feast for a bunch of us" (Frankenberg 2000:3).

4.5 Health Issues

At most of the sites, the "major type of [medical] case seen was upper respiratory diseases . . ." (717 ACW 1956:13). For emergency cases, evacuation was available to either Ladd or Elmendorf AFB. At times, however, the weather could intervene with threatening consequences. At Cape Newenham an airman had a heart attack. "Bad weather conditions prevented the air evacuation for five days. The Site Medical Technician was continually in contact with doctors at Elmendorf Hospital for information and advice. The Medical Technician kept a constant day and night vigil over the patient and no difficulties were encountered. . . . The patient is still at Elmendorf Hospital for rest and observation with no major complications" (794 ACW 1966:5).

Psychological difficulties seem to have been more of a health issue at the remote and isolated sites. As Staff Sergeant Rudy Corral (1999), who was stationed at Campion, put it: "NO family . . . NO McDonald's . . . seeing the same people every day for a year. . . no escape from work because you live there . . . Not being able to travel. . . ." Occasionally, someone would not be able to cope with such conditions.

The conditions could also exacerbate a pre-existing condition, as in one serviceman's account of "a terrible First Sergeant . . .who I truly believed was a sick man. He would pick fights with airmen over insignificant issues and then blow them up into formal investigations. . . . I believe that he did more to hurt the morale of the troops than anyone I have ever dealt with in or outside the military. He was not suited for this assignment. He was a mean, angry, evil man and wherever he went problems were sure to follow."

A sense of humor seems to have been one of the best medicines for psychological stress encountered at the sites. For example, Airman Deyton (1999) recalled "attending several seminars and discussion group meetings," at Kotzebue, "conducted by psychologists under contract to the AF to determine why morale was a problem on remote, isolated duty stations."

4.6 Buildings

To the earlier veterans who were on tour when the AC&W installations were of recent construction, the buildings were seen in a positive light. “I remember the overall condition of the installations [at Unalakleet] as being quite good . . . (Prew 1999:3). Men stationed at later dates usually noted that the structures had been kept up. ”Everything was old but well maintained," recalled Sergeant Raymond Carolin. “Our buildings were old . . . well lit, heated and kept spotless.”

All quarters had blackout shades for sleeping during the day (when on night shift) and during the days of summer when the daylight lasted 24 hours. Single rooms (usually shared by two men if NCOs) were for officers and some operations personnel such as radar men, while a common barracks was often used for the rest. Wikoff, a radar operator at Cape Newenham, had a “small room [that] was furnished sparsely. A discarded barrel used originally for some unknown purpose became a footstool.” Sunder, a teletype and switchboard operator at Sparrevohn in the mid-1950s, had quarters that were “adequate, cramped . . . shared a Quonset hut with approximately ten (10) others . . . . one long row of bunks and an aisle with a big old oil heater at one end. The guys at one end baked and the guys at the other end were ‘chilled’.”

The Indian Mountain AC&W Site under construction, circa early 1950s (Source: 11 AF archives).

Buildings were originally built of wood and on a standard Air Force layout with some exceptions for the extreme conditions. Mitchell’s description of those at Northeast Cape is typical: “The buildings at the main site were all connected via hallways [called arctic corridors]. I do not recall how many actual buildings existed, I would estimate eight or ten structures which housed the entire facility . . . , living quarters, mess hall, administrative offices, recreational areas and support equipment (power, water & heating). An out-building (the Military Affiliate Radio System radio station) was about one-half mile to the south of the main site, along the road to the tram [to] the top of the mountain where the radar transmitter/receiver and antenna [were] located."

Modular building construction, circa 1950s, at an unknown site. Modular buildings allowed more rapid field construction during the shortened field season (Source: 11 AF archives).

Later buildings were improved. Master Sgt. Thomas Gwizdak, at Cape Lisburne in the 1970s, stated that the main building [containing most support facilities of the lower camp under one roof] "was built with some of the top construction methods, sort of state of the art. The inside was built with sheet-metal studs, gypsum board and wallboard screws. . . . The out buildings were wood and were 50s vintage. The top site, where the radar was, [was] old and primitive."

4.7 Construction

Initial construction of the AC&W installations was usually accomplished in a year or two, depending on weather conditions and reliability of supplies. The brief building season was a common problem during any period of construction. At Campion it was reported that "due to the short summer construction period a serious problem exists in housing shortage, transportation facilities and construction hazards. Apparently, every team is required to work at the same time. High winds and rain cause safety hazards and often times stop construction progress entirely" (743 ACW 1961). The hazards were real. At Indian Mountain, a private "was killed by a D-8 tractor, which he was operating, while working on the runway turnaround" (708 ACW 1953).

Maintenance often included repair or replacement. At Cape Newenham "there was considerable difficulty [encountered] in this installation of the new [rigid] radome, because of . . .high winds. . . . [For] three days winds (80 – 90 knots) continued to increase [and] completely demolished the partially completed radome. . . . The entire antenna reflector had to be replaced because of wind damage (794 ACWS 1960).

4.8 Electronic Equipment

The installations existed for the radar. Carolin, stationed at Murphy Dome, recalled that as a "scope dope," he "would have to 'watch' the radar scope for nearly eight hours. Often the hours were passed watching a blank screen as there was no air traffic at all." He was also "responsible for assisting the commissioned officer . . . in directing fighter interceptor aircraft to their targets. In those days, fighter pilots . . . relied on us to plot the intercept points and direct them to their targets and then to assist them in a resulting air battle."

Others recall a rotation of duties to avoid the dreariness of scope watching. At Unalakleet, "the first hour might be operating a radar scope. The second hour you might move to the vertical plotting board, from there to the recorder-teller position, then to the Height Range Finder, to posting the weather board. Some sites you had to wear a .45 and be the door guard for an hour" (Mahaney 1999:1).

Maintenance varied in quality. When Henry Brand, Airman Radar Repairman, was at Murphy Dome in the mid-1960s (5 years before Carolin's tour), he found the "FPS-6Bs [radar units] were not well maintained. . . working shift duty, I personally improved the reliability of the magnetrons from a life expectancy of about 250 hours to about 1200 hours and increased power output primarily due to my earlier experience at Havre AFS, MT."

As for the communications equipment, Sunder, who was at Sparrevohn in the mid-1950s (before WACS), stated that the "teletype machines and switchboard were OK for their time I suppose. The problem was getting the transmissions to Elmendorf AFB . . .via radio. . . [which] . . . was down much of the time. Apparently, it was just inadequate. I recall shouting into the telephone and listening intently for a reply much of the time. The teletype machines spent much of their day just chattering away with a bunch of gibberish. We just turned them off. . . ."

Qualified personnel was a recurrent problem. A Unit Quarterly History from Murphy Dome sounded a common complaint: "A critical shortage in Computer personnel qualified to maintain the AN/FYQ-9 exists at the present time. . . The low manning level noted in the Electronic field (Air Force wide) presents a serious problem." Manning is at 68 percent authorized and about half are below the 5 skill level. Often, contract civilian personnel and electronics firms were called in (626 ACW 1961). "Experienced personnel [from] Philco

Electronics Division [are] training our airmen" (626 ACW 1961). At Murphy Dome, "General Electric depot assistance was required to repair a broken drive arm on the antenna assembly [of the AN/FPS-6A prime height radar]" (744 ACW 1959).

Service men manning electronic equipment, unknown date (Source: D. Halstead).

The equipment itself was usually described as satisfactory. The radar "was very good" and the communications equipment was "adequate for the job" (Breedlove 1999:3).

During the 1964 earthquake, when all contact between Murphy Dome and Elmendorf was lost, "MARS [Military Affiliate Radio System] became the only link to the outside world with the White Alice microwave system knocked out . . ." (Brand 1999:4).

4.9 Support Facilities

The chief concern of men stationed at AC&W sites, beyond staying warm and dry and fed, was mail delivery. Because it was the servicemen's only contact with their families, friends, and loved ones they left at home, the mail served as an antidote to the remote isolation of their assignments. Thus, when mail was delayed, especially if during the holidays of Thanksgiving and Christmas, morale plummeted.

At Sparrevohn, in the mid-1950s, "mail service was spotty, depending on the weather. We went for a couple of weeks without any mail or replenishment of supplies because of the weather" (Sunder 1999:3). At Kotzebue in the mid-1960s, "mail service was regular (approximately once per week except during severe weather)" (Deyton 1999:2). At sites located closer to main population centers, mail was more reliable and frequent. "Mail service was exceptionally good. A mail truck would depart each morning after breakfast . . . into town [Fairbanks]. . . . We had daily mail service and this went a long ways to maintain good morale" (Carolin 1999:21). At all sites, it seems that the "most anticipated announcement . . . was 'Attention in the Area . . . Mail is UP'" (Carolin 1999:21).

Electric power and heating were generally well maintained. At Ft. Yukon, they were "excellent. All utilities were generated at the site with a whole bank of 600 kw [kilowatt] generators" (Deits 1999:3). Indian Mountain "never had any electric difficulties" (Green 1999:4). Other airmen recall similar adequacies in terms of power supply. At Cape Newenham, "the radiators would 'pong' and hiss when they provided their steam heat" (Wikoff 1999:3). Problems could arise, however, as with the upper camp at Cape Romanzof where soot was blown over the radar tower by high winds through the exhaust stack, necessitating shut downs of the oil furnace (795 ACWS 1955:12-13).

Water storage was sufficient but continually suffered problems with freezing during the winter, especially at more remote bases. Cape Newenham "had a water freeze in February every year. Well water froze and water restriction was in place for four weeks. One shower a week" (Brown 1999:3). At Indian Mountain "we were on water rationing year round. There was a water reservoir from melted snow, a water line had to be reconnected in the summer and water then pumped to our water storage tank" (Green 1999:4). Bursting pipes were not unknown. Gwizdak reported how the "top site was on its own diesel power; however, the power wasn't enough to keep the water unfrozen and the pipes burst and they lost most of their water. . . . [An emergency supply was flown in] to the top camp until it thawed enough to fix the pipes."

If water supplies could freeze easily, so could sewage systems. At Tin City, it was reported that "the sewage disposal system at hilltop is inoperative due to freezing of the drain. Until this problem can be solved, the sewage disposal problem is acute. . . . heating cable has been procured but installation has not been accomplished [until] the weather is less violent" (Galvin 1999:1, 2).

4.10 Transportation

The use of transport modes in and around the sites was another feature of life at AC&W stations. Vehicles at some of the sites were "kept housed at all times in the winter." At Ft. Yukon, they "were used primarily for picking up mail and passengers from the local airport" (Deits 1999:3). In some cases the vehicles were "old, but serviceable" (Lowe 1999:2-3; Owen 1999:2). Mitchell recalled that, at Northeast Cape "we had only a few vehicles, a couple of weapons carriers (3/4 ton truck), a couple of two and one-half ton trucks, a jeep or two, one piece of fire equipment and a couple of Weasels, a tracked all-terrain type vehicle."

Many AC&W installations were located in areas where transportation was difficult by roadway. Waterways and air provided transportation routes at those locations.

Servicemen in boats, unknown date and location (Source: A. Biron).

4.11 Supplies/Requisition

Master Sgt. Kenneth Owen (1999), a cook at Campion from 1963-1964, recalled that "the supply system for fresh food (produce, eggs, fruit) out of Elmendorf" was a problem. "We would get a shipment about every two weeks, but the quantities shipped were not adequate for the number of personnel. . . ." He later discovered that at Elmendorf "the food stuffs were divided up for the sites evenly, with no regard for the number of personnel assigned." He stated that "'Mona Lisa' (re-supply) barges arrived in June, this was the sole one year supply of frozen meat, canned goods."

Bad weather often held up supplies. Typically, a station would go "for a couple of weeks without any mail or replenishment of supplies because of weather" (Sunder 1999:3). The wind could also delay supplies, as at Cape Lisburne in the mid-1970s when the "wind caused problems and there were weeks that went by without any support aircraft coming in with mail, supplies, and movies" (Gwizdak 1999:3).

For coastal radar sites, the major mode of resupply during the summer months was "by barges called 'Mona Lisa'. . . ." At Northeast Cape, there were "Eskimo workers who would travel with the tug and barges to off load them at each site" (Mitchell 1999:3).

4.12 Lifestyles

Relatively standardized conditions prevail at military installations, especially among stations sharing a special function in a special region. Yet, there were not only variations of similar lifestyles among the personnel, but also several notable differences.

Off-hours dancing at Cape Lisburne AC&W Site circa 1970. Reasons for jubilation ranged from holidays to end-of-tour sendoffs (Source: 11 AF archives).

4.12.1 Daily Activities

A "typical" day on the job "depended entirely on one's specialty. Most personnel were engaged in shift work" which was rotated (Deits 1999:4). Airman Deyton, who was a radar repairman at Kotzebue, described his shift work: "Breakfast at 0600, work in shops till 1130, lunch till 1200, work through 1700, dinner, then free time. All maintenance personnel worked rotating shifts with three days of day shift, three days of swing shift, three days of midnight shift, then three days off but on call for emergency maintenance" (Deyton 1999:3).

As an example of nonshift work, Airman Mitchell was a radar operator at Northeast Cape. A typical work day "was to rise at about 0630, walk to the dining hall, have some breakfast then go to the MARS [Military Affiliate Radio System] station [and] maintain radio contact with Elmendorf and the other radar sites, travel back to the site for lunch, then back to work till about 1630. Sometimes I would stay at the radio building and operate the equipment on the civilian amateur radio frequencies as KL7FAR" (Mitchell 1999:4).

A cook's job differed somewhat from the rest of the personnel. Airman Owen was a cook at Campion. "I worked from 2100 hrs. to 0500 hrs., seven days a week as the Night Cook, and I worked for 72 straight nights without a night off, but what else could you do!" (Relief came after six months as midnight cook, when he was switched to day cook and then baker [Owen 1999:1, 3].)

4.12.2 Dining Hall and Food

Regarding food, nearly all accounts of the fare provided at the dining halls are positive. Because food was of central concern, the dining facilities tended to be one of the major centers for congregating and socializing when off duty. Referring to King Salmon and Cape Newenham, having served at both sites, Brown recalled: "Food at both sites was good. Never had a meal I couldn't eat. At Cape Newenham, we had a coffee area near the living quarters where you could go anytime of the day or night and get a cup of coffee and any pastry, cake, or cookie the mess hall sent up. I personally liked mid-night chow. . ." (Brown 1999:4).

The dining hall at Indian Mountain AC&W Site, circa 1950s/ 1960s (Source: 11 AF archives).

At Tin City, Galvin stated that the "dining hall and facilities were standard military issue. Overall the food was fairly good considering military standards. Food was either frozen or dried." The Master Sergeant cooks "were food service specialists . . . [who] knew how to take the standard military menu and make it fairly attractive. . . . next to getting mail this was the most important factor in maintaining morale" (Galvin 2000:4).

Cape Newenham's "dining hall was the center of our world. It was where we ate. It was the coffee house and conversation center. It was where we got to know each other. It was where we were entertained by the one USO show that would visit that year" [1974-1975] (Wikoff 1999:3). At Unalakleet, the "dining hall was one of the focal points of the site. It was open 24 hours a day and coffee was always available. You could always find someone to talk to in the dining hall. Our baker "Pop McQuisten" made all baked goods on site. He was a treat and worked at night baking the breads, cakes or whatever was necessary. The food was well prepared and there was a good variety. Fresh fruit and vegetables were limited by the flights we got in, and we got powdered milk, which wasn't the best in those days [1962-1963]" (Greenleaf 1999:2). The same was reported about eggs: "Dining hall was clean and neat. The food was okay — I remember the eggs being from long term cold storage (not spoiled but a long way from fresh!)" (Prew 1999:4).

4.12.3 Recreational Amenities

Recreational amenities at the installations during off duty tended to be similar on-site at each of the stations and varied considerably off-site, depending on the distance from communities and local variations in the natural environment.

The library at Indian Mountain AC&W Site, circa 1950s/1960s (Source: 11 AF archives).

The on-site facilities at Fort Yukon were typical. "We did have one multi-purpose building which served as day room, movie theater, bowling alley. There were also a number of hobby shops such as leather, ceramics, wood craft photography, etc. And, of course, there were a couple of clubs - one for the Officers and one for the enlisted troops" (Deits 1999:5). Sites also included a NCO club, often pool tables, ping pong, a basketball court, and a library (Mahaney 1999:2; Greenleaf 1999:3; Gwizdak 1999: 3). A great deal of reading and listening to music was done, as well as card playing (Brown 1999:4; Lowe 1999:3; Tepe 1999:4). Movies usually were shown several times daily to make them available for each shift coming off duty; they tended to be a major attraction.

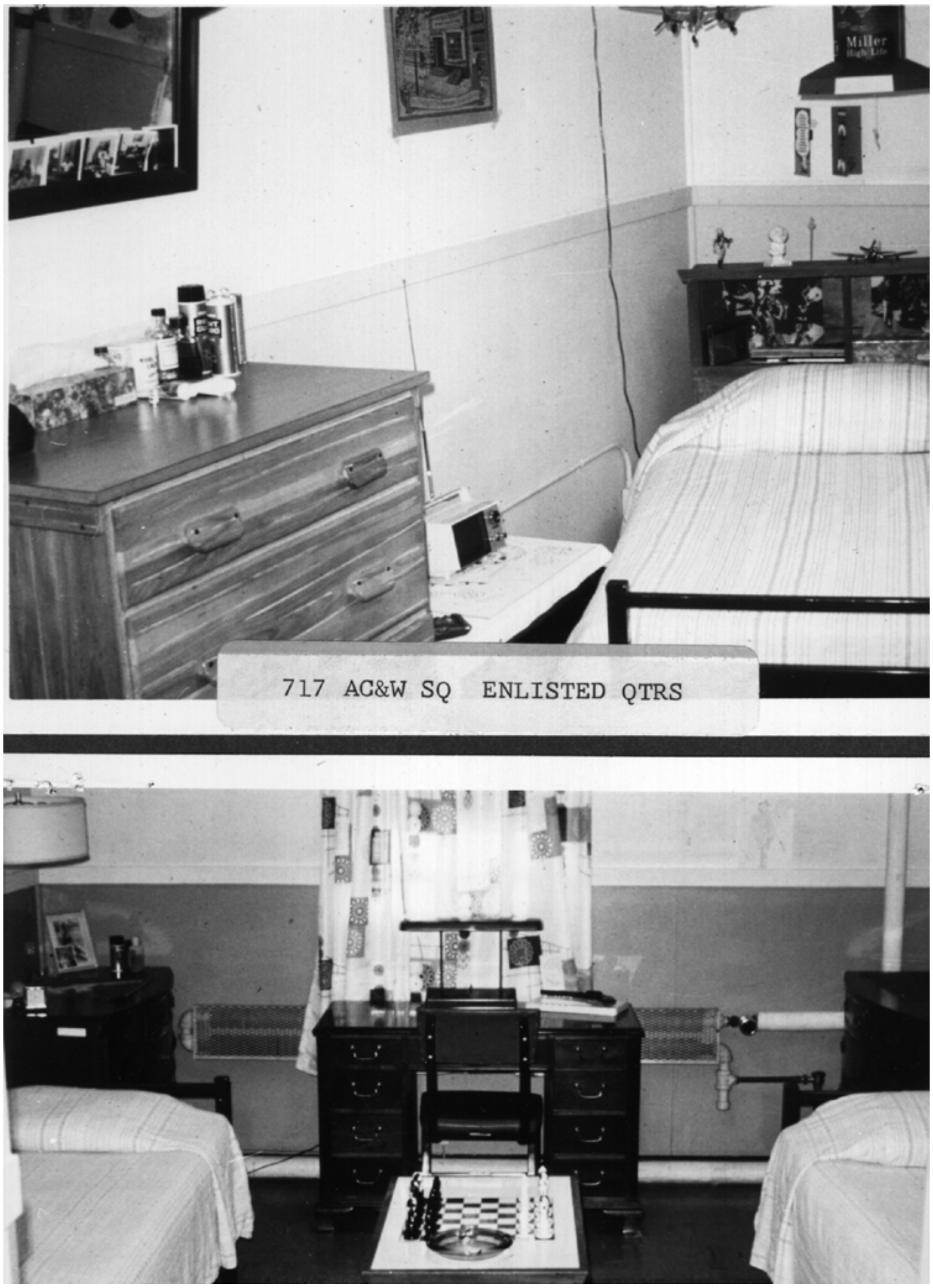
When weather permitted mail flights, "five current films" arrived for "movies five days a week. If weather conditions prevented this for any period of time, you pretty much had [the movies] memorized by the time the new batch arrived" (Galvin 2000:6). The USO shows were also looked forward to, if for no other reason than the presence of females. Galvin reported that at Tin City there was only one show and that the others scheduled had to be canceled because of bad weather. "This didn't help morale much as this was the only opportunity we had to actually see a female even if only for a few hours" (Galvin 2000:6).

AC&W personnel fishing, unknown location and date (Source D. Halstead).

Off-site recreation ranged from fishing, hunting, or hiking to catching a ride into town to take in the local amenities. At Murphy Dome, Carolin recalled "I went to Fairbanks quite often, taking in the [sights]. We used to take the mail truck into Fairbanks . . . and get a cot in a dorm room for $3.00 a night at the local USO" (Carolin 1999:24). Ft. Yukon was located far from any metropolis, but "was a recreation mecca for the outdoors minded. We had excellent fishing, hunting, dog-sledding, snow-mobiling, softball. We frequently played softball against a team from the Indian village, both summer and winter (on snowshoes). We had the only dog sled teams in the AAC [Alaska Air Command], as far as I know" (Deits 1999:4). Other sites, such as Cape Lisburne and Northeast Cape, were less fortunate, their locations imposing severe limits on off-site activities.

4.12.4 Morale

Morale at AC&W sites has been described as good, qualified by consideration of the relative degrees of isolation and weather-imposed problems of mail and supply deliveries. A sense of the importance of the mission and pride in a necessary job being well done seems to have bolstered morale, despite the adverse conditions.



Typical enlisted men's quarters at Tatalina, unknown date. NCOs and operations personnel had two-man quarters. Men reported that the steam heaters were often noisy and "pinged." (Source: 11 AF archives).

At Murphy Dome (one of the least adverse assignments) "morale was generally good but there always seemed to be more tension in the air and certainly more physical fights among the troops" (Carolin 1999:22). The factors making up remote assignments, Galvin observed, had "the ingredients for explosive situations," and he attributed the fact there were so few incidents "to the quality of the NCOs," a number of whom "were World War II and Korean veterans who possessed a great deal of experience and maturity and were able to deal effectively with these situations" (Galvin 2000:8).

"Morale was exceptionally high," at Fort Yukon, "both individual and the unit." The one "problem child" had to be "airlifted out to Elmendorf" (Deits 1999:4). Campion's morale was "VERY GOOD. We stuck together like a family . . . everyone looked after each other!" (Corral 1999:3).

Remote assignments were harder on married men. "I think my morale was fine," related Owen about Campion. "I think the squadron morale on a whole was good. Of course . . . a remote site was a one year isolated tour, with no break, leaves, etc., so some of the married troops had it a lot worse than us singles" (Owen 1999:3).

Greenleaf, at Unalakleet recalled "my morale was not bad except for one occasion" when "I wasn't allowed to go home for the funeral" of "my father-in-law." He found that "family separation wasn't easy but we coped with it. . . I know of three cases of persons having a mental breakdown and trying to hurt themselves…" (Greenleaf 1999:3).

4.12.5 Memorable Experiences

Of the numerous memorable experiences recounted by nearly all of the veterans, few patterns emerge, except when a notable event, such as the President John F. Kennedy assassination or an escalation in United States – Soviet Union tensions, occurred. The following are selected examples of the variety of experiences.

Brian Coy (1999), Murphy Dome (1963-1964):

"The coldest experience was when JFK was killed. We had to mount a 24 hour perimeter guard, in case the Russians were able to land on the coast and trek overland to attack us. This was in the middle of a blizzard with white-out conditions. By the time we posted a set of guards it was time to relieve them and thaw them out."

"The 1964 earthquake. I had worked swing shift. After finally getting to sleep . . . and was just thinking about lunch when I felt the shake. . . .Just then the alert sounded. Because we were far enough from the epicenter to escape damage, we therefore became the control center for controlling and flight following the relief aircraft flying into Anchorage, and relaying messages between families unable to communicate in any other way."

James Mitchell (1999), Northeast Cape (1959):

"Watching Navy P-2V aircraft fly down the Bering Strait Sea exactly on the line between the USSR and Alaska, sometimes to be chased to the East by Russian fighters. We transmitted a code word to the P2 to alert them to the threat."

"Being there in Alaska, listening to the celebration on the radio when they became a state."

"Being outside at midnight July 4th 1959, playing softball with the sun shining and snow falling."

Kenneth Green (1999), Indian Mountain (1972-1973):

"In Nov 72 we had 2 men freeze to death. Spending an unplanned night in the arctic myself without any ill effects. Digging through snowdrifts up to 12 feet deep on the 4th of July 1973 trying to find our water line so we could get water pumped into our water tank. . . ."

Charles Deits (1999), Ft. Yukon (1966-1967):

"My personal experiences would be quite different from most personnel. Without permission from USAF, I moved my wife and 3 children to Ft. Yukon and lived off base in the Indian village. My site Commander was quite cooperative. . . .I . . . would [ride] a motor-cycle back and forth to work at minus 40-50 degrees in the winter months. Brrrr! Also, I killed 2 moose in one day on a hunting trip. . . . [and] I shared a lot of the meat with the local church and, of course, my family ate very hearty for a long time."

Raymond Carolin (1999), Murphy Dome (1969-1970):

"... . the 24 hour daylight in the summer . . . the beautiful aurora [borealis] . . . the chow food was excellent . . . 4 meals a day. . . ."

I had a telephone in my dorm room in case I was needed by the Combat Control Center . . . . [and] found out that by dialing a certain code number I could dial any military base in the world . . . [so I got myself patched through] . . . to my wife each morning. This perk certainly helped my morale! It was something that I could never tell anyone."

". . . I was responsible for what then was reported to be a 'legendary' ... 'all time' . . . 'Hall of Fame' bubble check. . . . I talked 4 fighter pilots into swooping down over Murphy Dome AFS and do a bubble check at 7:00 AM on a particular Saturday morning."

4.13 Mission Operations

As far as their thoughts about the mission at the time, the men were almost uniform in their belief in the importance of their role in Cold War air defense and in the feeling of doing a satisfactory job.

"I think that most personnel . . . were quite a-political. We were there to do a job which we knew was important, and we didn't dwell on things out of our immediate control. . . . We were all very much aware of the critical role of AC&W during this 'Cold War' era. We knew our jobs. We were good at them, and were ready to perform our mission" (Deits 1999:5).

The usual work of the radar sites involved participating "in numerous tracking operations, some of which did require the scrambling of interceptor aircraft . . . for identification. Our movements and identification section would routinely identify tracks as bush pilots, FAA sanctioned flights, or scheduled airlines" (Deits 1999:6).

Locations on the west coast, closer to Soviet air space, often had tracking operations involving Soviet aircraft. At Unalakleet, "many times Russian aircraft would start to come toward us and then at that imaginary line in the sky they would turn around. We often would scramble fighters but things always calmed down. I viewed this as a cat and mouse game because we did the same thing to them" (Greenleaf 1999:5).

5 NATIONAL REGISTER ELIGIBILITY OF AIRCRAFT CONTROL AND WARNING FACILITIES

In 1997, the 611th Air Support Group (611 ASG), in coordination with the Alaska State Historic Preservation Office (SHPO), determined that the Aircraft Control and Warning (AC&W) System meets the eligibility criteria for inclusion in the National Register of Historic Places (NRHP) for its significant contribution to national and Alaskan history and its important engineering design (i.e., National Register Criteria A and C).

Most AC&W installations did not retain sufficient integrity to be considered eligible for individual listing on the NRHP, either because they had already been entirely demolished or because critical components of the system were demolished. However, the 611 ASG determined that Cape Lisburne, Fort Yukon, Kotzebue, and Tin City retained enough original structures to be eligible for inclusion in the NRHP (611 CES 1998). Cape Lisburne was determined to be the best example among the four eligible sites.

The 611 ASG initiated a Memorandum of Agreement (MOA) with the Alaska SHPO and the Advisory Council on Historic Preservation (ACHP) to mitigate the adverse effects of environmental restoration and/or demolition of remaining historic properties at the AC&W sites by recording the system's history and remaining facilities (611 ASG et al. 1997). The MOA stipulated completion of the following recordation materials:

- Architectural recordation forms and photographs for all buildings at a representative installation (Cape Lisburne) using Historic American Buildings Survey (HABS) Level 2 standards as guidance,
- Site layouts of all other eligible installations (Fort Yukon, Kotzebue, and Tin City) using HABS Level 3 standards and guidance,
- Historical monograph of the AC&W system, and
- Historical booklet of the AC&W system.

Site layouts of the eligible sites were completed in 1999, and the architectural recordation forms and photographs were completed in 2000. This document, completed in 2002, represents the historical monograph (edited and revised in 2013), and the popular historical booklet was published in 2002. All documentation will be available from the Alaska SHPO and from the 611th Civil Engineer Squadron (611 CES) of the 611 ASG.

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APPENDIX A: RADAR AND ITS HISTORY

A.1 RADAR CONCEPTS

The basic concept of radar is relatively simple, although its practical application can be very complex. A radar's antenna transmits or radiates electromagnetic energy in the form of radio waves. These waves are reflected from objects (targets) that they encounter, and the resulting reflected wave (echo) is detected by the radar's antenna, producing an electric signal that goes to a screen where information about the target is displayed. Hence, "radar" stands for radio detection and ranging.

The radio waves of a radar unit are sent out in separate bunches, or pulses. Each pulse is a group of hundreds or thousands of cycles of radio waves. After each pulse, there is a pause when the radar is receiving, instead of transmitting. During that pause between transmissions, the echo of the previous pulse returns to the radar. Since the senders know how fast the wave is traveling, the time required for the return of the echo is used to compute the distance to the target. Because the waves travel at approximately 186,288 miles per second, a reflected echo comes back in a fraction - even a few millionths - of a second. A millionth of a second is called a microsecond. In one microsecond, a radio wave travels 984 feet. A radio wave travels to a target one mile away and returns as an echo in 10.7 microseconds. This trip is called a radar mile. A hundred radar miles would take about 1,000 microseconds (or 1/1,000th of a second) and constitute a round trip of 200 air miles.

Older radar system antennas, used to detect aircraft, rotate horizontally for search radar and horizontally and vertically for height finding radar. Modern radar systems are three dimensional and can provide search and height data from a single rotary antenna. On the display screen, the radar beam shows up as a straight line of light rotating clockwise around the screen, like a windshield wiper. On some screens, when the beam hits something (a target), it is reflected back as a received echo. The echo signal of the reflected beam is wiped onto the display screen as a "blip." A series of these blips can "paint" a picture of a large object. Ships using such radar can almost draw shoreline maps on the display screens or see other ships. Personnel on aircraft can use the radar to see or map the ground below them. The distance to the painted target on the display represents the distance to the object that reflected the radar beam (Girardin 2009).

In addition to range, or distance, of a target, other information about the target is also provided by the echo signal. The angular location, or azimuth, of the target can be found with a directive antenna to sense the angle of arrival of the echo signal. For a moving target, radar can derive its track, or trajectory, and predict its future location by comparing blips through time. For a moving target, the Doppler effect (change in frequency caused by a moving object - an object moving toward you increases the frequency, an object moving away from you lowers the frequency) causes a shift in frequency of the echo signal. This allows radar to separate moving aircraft from stationary land and sea clutter.

A.2 HISTORICAL DEVELOPMENT

The development and application of radar, an acronym coined by Lieutenant Commander S.M. Tucker and Lieutenant Commander F. R. Furth, who were instrumental in putting radar into effect, has had far-reaching historical and technological impacts. In its most elemental form, radar consists of an oscillator that transmits an electromagnetic wave, a receiving antenna, and a receiving and display device. A portion of the transmitted signal is intercepted by reflecting objects in the beam of the signal and reradiated in all directions. The receiving antenna collects the returned energy and delivers it to a receiver that processes the signal to detect the presence of a target, its location, and velocity (Skolnik 1980).

Radar detects objects by using electromagnetic waves. Expanding on the formal electromagnetic theory of James Clerk Maxwell during the early 1870s and classical experiments on electromagnetic radiation conducted by Heinrich Hertz during the late 1880s, Nikola Tesla in 1900 was the first to mention formally the possibility of using electromagnetic waves to both find the location of an object and determine its movement (Swords 1986). In 1904, Christian Hlsmeyer of Germany applied for a patent for his "telemobiloscope," which was a transmitter-receiver system for detecting distant metallic objects by means of electrical waves. His device was tested by correctly detecting the movement of a ship from the Hohenzollern Bridge in Cologne. At that stage of development, his equipment could detect a ship at a distance of 3,000 meters using an electromagnetic wave that had a wavelength of 40 to 50 centimeters (Swords 1986).

Another early German pioneer in the field of radar research was Hans Dominik. Together with Richard Scherl, the team built a device called the "strahlenzieler" (ray aiming device) that could be used to detect metal objects in the dark. The device successfully operated at a wavelength of 10 cm. However, because of the date (February 1916), the inventors were told that it was too late to develop the device further for use in World War I.

In September 1922, Albert Hoyt Taylor and Leo Clifford Young carried out very high frequency (VHF) experiments at 60 megahertz (MHz) at the United States Naval Research Laboratory (NRL). The NRL researchers positioned a radio transmitter on one shore of the Potomac River and a receiver on the other. When a ship sailing on the river passed between the transmitter and receiver, it caused fluctuations in the intensity of the received signal. The experiment is considered to be one of the first performed in the United States that demonstrated the radar effect for a bistatic configuration (i.e., one in which a transmitter is used in conjunction with a remote receiver). Although interesting, the Navy was unwilling to sponsor further work on the system.

In June 1930, renewed interest in radar arose at the NRL when Leo Young and Lawrence Hyland observed that an aircraft flying through the beam of a transmitting antenna caused a fluctuation in the received signal. This finding was not given a great deal of attention until people learned how to use a single antenna for both transmitting and receiving (i.e., monostatic radar).

During the 1930s, efforts to use echoes of radio waves for aircraft detection were initiated independently and nearly simultaneously in several countries in response to the prevailing political climate. These countries included the United States, Great Britain, Germany France, the Soviet Union, Italy, and Japan. In the United States, much of the research was performed at the NRL.

Between 1931 and 1934, all research conducted at the NRL concerned continuous-wave (CW) or Doppler methods of detection (i.e., methods that rely on detecting a change in frequency caused by movement in the target). A demonstration of the CW aircraft-detection system for the Naval Appropriations Subcommittee was conducted at the NRL in February 1934.

Between March and December 1934, Robert Page of the NRL assembled an experimental radar set that used pulsed radiation rather than a continuous wave. In this system, two Raytheon RK-20 tubes were keyed by an asymmetric multivibrator to produce pulses with a duration of somewhat less than 0.00001 s (10 microseconds), spaced at intervals of 100 microseconds. The peak pulsed power was estimated at 100 watts. Efforts then began to improve the efficiency of the system. On April 28, 1936, the system picked up an aircraft at a distance of 2 ½ miles. On April 30, 1936, the system detected an aircraft at a distance of 8 miles. By June 1936, the range had been extended to 25 miles by increasing the voltage in the amplification tubes to 15,000 volts. Because of its apparent importance, the NRL radar program was classified as "secret" in 1936 by the United States government.

In early 1937, a similar system was tested at sea aboard the destroyer USS Leary. This system operated at 200 MHz. A range of 20 miles was obtained for aircraft. Additional modifications were made, including redesigning the receiver and using a rotating antenna. The new system was completed in February 1938, and the NRL installed an operational radar system aboard the battleship USS New York in December 1938. The system was designated Model XAF. With Model XAF, aircraft could be detected at ranges of 120 miles, surface ships at 18 miles, birds at 6 miles, and terrestrial terrain at 80 miles (Swords 1986). By 1941, 19 of the systems were installed on major ships of the fleet (Skolnik 1980).

The United States Army Signal Corps also had an interest in radar development during the early 1930s. By December 1936, the Army tested its first pulsed radar, which had a range of 7 miles. The first operational radar used by the Army for antiaircraft fire control was the Signal Corps Radar (SCR)-268, which became available in 1938. Because of poor angular accuracy, the system also employed searchlights to light the target. The SCR-268 remained the standard fire-control equipment used by the Army until January 1944, when it was replaced with the SCR-584 microwave radar. This new system did not require searchlights or optical angle tracking. The Army was also interested in long-range detection of aircraft. In 1939, the Army developed the SCR-270 for early warning. The attack on Pearl Harbor in December 1941 was detected by an SCR-270 radar in Honolulu.

A.3 RADAR DEVELOPEMNT DURING WORLD WAR II

At the start of World War II in 1939, most of the countries involved had some form of operational radar equipment. Germany had progressed further than any other country. The Germans employed radar on the ground and in the air for defense against Allied bombers. Radar was installed on a German battleship in 1936, about 3 years before a similar installation by the United States. In 1940, the Germans halted radar development in the belief that the war would soon be over. Great Britain and the United States, however, accelerated their efforts.

All of the radar systems that were in operation at the start of World War II, except for some German radars, operated in the VHF band, at frequencies less than 200 MHz. The use of VHF frequencies posed a number of problems:

- the width of the transmitted beam is broad, which limits accuracy and resolution, and the system does little to exclude unwanted echoes from the ground or other stationary sources (false positives);
- the VHF portion of the electromagnetic spectrum does not permit the wide bandwidths needed for short pulses that allow greater accuracy in determining the range of a target; and
- VHF frequencies are subject to atmospheric noise, which limits the sensitivity of the receiver.

A transition to higher frequencies (i.e., frequencies higher than the microwave portion of the electromagnetic spectrum) occurred in late 1939 when the cavity magnetron was invented by the British (Buderi 1996). In 1940, the British disclosed the concept of the magnetron to the United States via the Tizard Mission. It then became the basis for the work performed by the newly formed Massachusetts Institute of Technology (MIT) Radiation Laboratory at Cambridge, Massachusetts. In 1940, the British magnetron was capable of producing a peak pulse of 10 kilowatts at 3,000 MHz, a 100-fold improvement over anything previously achieved at centimeter wavelengths. Use of the magnetron in radar systems overcame many of the difficulties inherent in the lower-frequency devices previously used (Buderi 1996).

About 150 different radar systems were developed at the Radiation Laboratory at MIT while it was in operation between 1940 and 1945. One of the most notable radar systems developed was the SCR-584, which was widely used as a gunfire-control system. The SCR-584 operated in the frequency range of 2,700 to 2,900 MHz, fully a factor of 10 greater than the frequencies used in radar systems at the beginning of the war.

A letter code was used by the Allies during the war to describe particular radar operating frequencies. Actual frequencies were not used for security reasons. In the United States, P-band radars operated between 225 and 390 MHz, L-band between 390 and 1,550 MHz, S-band between 1,550 and 5,200 MHz, and X-band radar between 5,200 and 10,900 MHz. These designators are still employed today in defining classes of radar systems (Swords 1986).

Radar had many applications during World War II, including aircraft detection, precision gunfire-control, and long-range aircraft navigation. Radar was installed on the ground, on ships, and in aircraft. In the area of aircraft detection, both the location of the aircraft and its altitude were determined. In addition, information was available for tracking the aircraft. This information was vital for a timely, successful interception. Shipboard radar was used for both aircraft detection and for navigation, including locating buoys, shorelines, and other ships. Airborne radar was used to detect other aircraft and ships and for navigation. Radar was also a vital component of fire-control systems (i.e., systems used to supply antiaircraft fire, and aim and direct fire at other desired targets). In addition to these detection and fire-control applications, radar was also used as aircraft altimeters. In this application, a frequency-modulated instrument detects the ground as a target and indicates the distance.

A.4 POST WORLD WAR II RADAR DEVELOPEMENT

After the end of World War II, progress in radar technology slowed down measurably. The last half of the 1940s was dedicated to completing and refining developments initiated during the war. Some of these developments included moving-target indication (MTI) radar, which used the Doppler frequency shift to eliminate stationary clutter, and monopulse tracking radar.

During the 1950s, new and better radar systems emerged. One of these, the AN/FPS-16, was a highly accurate monopulse radar system capable of an angular accuracy of about 0.006 degrees. In addition, large, high-powered radars designed to operate at 200 and 450 MHz were developed. These systems had large, mechanically rotating antennas (in some cases more than 120 feet wide). The klystron amplifier was also introduced in the 1950s. This invention provided a stable source of high power for very long-range radars. Synthetic aperture radar (SAR) also made its first appearance in the 1950s. SAR uses resolution in the Doppler shift frequency to provide the equivalent of cross-range (i.e., angular) resolution. In essence, it operates by creating a series of stored echo signals from a moving antenna and then processes these signals to create an image similar to one obtained from a large-diameter antenna. This type of radar system was, however, not completed until the 1980s.

Also during the 1950s, important theoretical concepts were published, helping establish radar on a quantitative basis. Some of these concepts included:

- the statistical theory of detecting signals in noise;
- configuring radar receivers to maximize the detection of weak signals (matched filter theory);
- the Woodward ambiguity diagram, which clarified the tradeoffs in waveform design for good range and radial velocity measurement and resolution; and
- the basic methods for Doppler filtering.

The first large electronically steered, phased-array radars were put into operation in the 1960s. Many of the attributes of the high-frequency, over-the-horizon (OTH) radar (also called sky-wave radar) were also demonstrated during the 1960s, as were the first radars for detecting ballistic missiles and satellites. OTH radar systems operate at shortwave frequencies (3 to 30 MHz). Although the high frequency band is generally classified as occurring between 3 and 30 MHz, for radar usage, the lower frequency limit lies just above the broadcast band (around 2 MHz) and the upper limit can extend to 40 MHz or more. These frequencies are used to take advantage of ionospheric refraction, which allows targets to be detected at very large downrange distances (600 to 2,400 miles), well beyond the curvature of the earth (Skolnik 1980). The ionosphere is that part of the earth's atmosphere that extends in altitude from about 70 to 500 kilometers (44 to 310 miles). In that part of the atmosphere, ions and free electrons exist in sufficient quantities to reflect and/or refract electromagnetic waves. OTH systems can also be used to detect missiles, particularly the atmospheric disturbance caused by ballistic missiles as they travel through the ionosphere.

Radar systems specifically designed for detecting and tracking missiles and orbiting satellites are much larger than those used for aircraft detection because the ranges must be larger. Such radars might be required to have maximum ranges of 2,400 to 3,600 miles, compared with a typical range of 240 miles for a long-range aircraft detection system. Because of the need for an extended range, missile tracking systems operate with a power level about 100 times greater than the power required for aircraft detection. Antennas for missile detection are also very large and can be up to 100 meters wide. These antennas are then electronically scanned and phased so that the objects can be tracked without mechanical movement. The Pave Paws radar (AN/FPS-115) is a phased-array radar system for detecting missiles launched from submarines. It has a range of 3,600 miles. An upgraded version of this radar system is used in the Ballistic Missile Early Warning System (BMEWS) network, with installations in Alaska, Greenland, and England.

A.5 RADAR COMPONENTS

Radar is not a single device, but, rather, a complex of electronic and mechanical devices for the purpose of gathering information about distant targets provided by their reflections of radio pulses. To accomplish this task, a radar system must synchronize the requirements of transmission, reception, processing, display, and control.

The transmitter must generate short pulses of very high power. The power source for transmitting radio pulses was initially the magnetron, an oscillating device for producing a waveform. Power amplifiers, especially the klystron, could produce much larger average power and proved more stable. The klystron made it easier to achieve pulse compression, MTI radar, and pulse Doppler radar (Skolnik 1980).

The transmitted power is radiated into space by a directive antenna that concentrates the energy into a narrow beam. The Aircraft Control and Warning (AC&W) System used two parabolic forms: the dish and the parabolic cylinder. A dish focuses the energy into a pencil beam, giving high resolution and minimum bandwidth (on the electromagnetic band). A parabolic cylinder achieves the same effect in a single plane and, in addition, allows the use of a linear array for the receiving antenna in the other plane. The result is more flexibility in shaping or steering the beam (Skolnik 1980:6.10-6.11). These surveillance antenna provide only range and azimuth, or two-dimensional, information. They need different height-finding equipment to measure the third dimension, such as a vertical receive-only line array mounted on a 2D surveillance radar, or use of two apertures on the same rotating antenna shaft, the second aperture emitting a fan beam tilted from the vertical plane (Skolnik 1980:20.6). Separate height-finding antenna were also developed, such as the nodding antenna. For this type of radar, a horizontal fan beam is mechanically scanned in elevation by rocking or "nodding" the entire antenna structure. The pulsed radar beams form overlapping lobes, and as the beam traverses the target, its echoes are displayed by a range-height indicator (RHI). The information allows the operator to determine the target's height by estimating the center of the displayed image, a process called beam splitting (Skolnik 1980:20.3).

The size of antenna required for a radar system depends on such factors as desired frequency, stationary or moving location, and operating environment. Mechanical and electrical tolerances are proportional to the wavelength. Therefore, at microwave frequencies, radar antennas are seldom larger than 10 or 20 feet (Skolnik 1980:1.4). Servomechanisms provide mechanical control of the antenna. It might need to rotate constantly while sending a beam vertically, from horizon to zenith, or it may need to scan a small sector. Its movements also have to be coordinated with other functions.

Operation of a radar unit requires that the receiver be turned off between pulses when the transmitter is operating, and that the transmitter be turned off between pulses when the receiver is operating. This process requires a duplexer device that acts as a rapid switch to turn the transmitter and receiver on and off at precise intervals measured in microseconds. This must be done hundreds of times each second. The signal collected by the antenna is sent to the receiver, which must separate the desired signal from the ever-present clutter signals and amplify the signal for either immediate display or to allow computer processing (Skolnik 1980:1.4).

Control of the radar pulse includes operating at different frequencies within a radar band, using different waveforms and signal processing, and determining pulse length, and length of time between pulses, or the pulse repetition frequency (PRF). Control of the various parameters is necessary to maximize radar performance under different environmental influences, such as weather, clutter, external electronic interference, and hostile electronic countermeasures (Skolnik 1980:1.5-1.6). These requirements were initially chosen by an operator and later could be made automatically by computerized radar control.

The display device for surveillance radar is usually a cathode-ray tube (CRT) with a plan position indicator (PPI) format. The PPI provides a map-like picture of the target's location in polar coordinates of range and angle (Skolnik 1980:1.5). A cathode ray tube functions by producing a narrow beam of electrons and directing them against a display screen. When the beam strikes the screen's coating of phosphorescent material, it glows. Magnetic or electrically charged plates can move the beam, "painting" a picture on the screen that represents the distance and location of a target reflecting the radar pulses.

There are other component requirements for radar. Because of the extremely high frequencies used by radar, the electromagnetic currents cannot be conducted along ordinary wires. They are either piped or carried in coaxial cables. These waveguides are called “the plumbing.” Radar also requires another component called a synchronizer, which is a device for signaling the cathode ray tube at the start of each pulse so that the correct amount of time will appear when the echo is received back from the target.

In addition to the radar hardware components discussed above, a radar system must be enclosed in a structure to protect it from the weather. Thus, radomes are an additional required component for the operation of radar in severe environments, such as those encountered in Alaska. The ideal radome should be completely transparent to the radio beams from and to the antenna while withstanding wind, rain, hail, snow, ice, and other environmental effects. In practice, the mechanical design of the radome is determined by the environmental factors, with compromises on radiation transparency. Radomes fall into two main categories: ground and ship-based radar; and airborne or missile systems. In the first category, various skin and skin-supporting designs have been developed to minimize electrical effects within environmental constraints. Radome skins are either air-supported or supported by a framework (Skolnik 1980:6.44).

Ground and shipboard radomes are commonly truncated spheres mounted on a tower or directly on the ground. The first large radomes were air-supported, inflatable structures. However, failure of the internal air pressurization equipment can cause loss of the radome and the antenna. The alternative, structures with solid frames, also have disadvantages. Although they are sturdier, the metal frame of frame-supported radomes can scatter the radar signal. This impact has to be factored into calculations giving the total radiation field of the antenna in the presence of the radome (Skolnik 1980:6.47-6.48). The effects of radome panels on antenna performance also have to be taken into account.

A.6 TYPES OF RADAR SYSTEMS

Radar systems can be categorized according to the function that they perform. Some of these functions include aircraft surveillance, surface (ground or sea) surveillance, space surveillance, tracking, fire-control, missile guidance, instrumentation, remote sensing of the environment, intruder detection, and underground probing. They can also be classified according to the radar technique they utilize. Specific examples include simple-pulse radar, moving-target indication (MTI) radar, airborne MTI, pulse Doppler radar, high-range resolution radar, pulse-compression radar, synthetic aperture radar (SAR), inverse SAR, side-looking airborne radar (SLAR), imaging radar, tracking radar, tracking-while scan radar, 3D radar, electronically scanned phased-array radar, continuous-wave radar, and frequency-modulated, continuous-wave (FM-CW) radar. Brief descriptions of these systems are given below.

A.6.1 Simple-Pulse Radar

Simple-pulse radar is the most commonly used system. It generates a series of short-duration pulses that themselves contain a sine wave of higher frequency electromagnetic radiation. The width of the pulse is on the order of microseconds. The pulse repetition period is on the order of milliseconds. The peak power of the pulse is on the order of a megawatt. The average power can be measured in kilowatts. Upon striking a target, a weak signal is projected in all direction, including the direction of the receiving antenna. This type of radar can be thought of as conventional.

A.6.2 Moving-Target Indication Radar

MTI radar uses the Doppler frequency shift of the received echo signal to detect moving targets and to reject unwanted signals from stationary objects that produce clutter. In Doppler shift, an object moving toward a receiver will produce a shift in the frequency toward higher frequencies (shorter wavelengths). An object moving away from the receiver will shift the frequency toward longer wavelengths (lower frequencies). Almost all ground-based aircraft surveillance radar systems use some form of MTI.

A.6.3 Airborne Moving-Target Indication Radar

An aircraft radar will experience Doppler shifts in frequency from stationary objects such as the ground and the sea because of the motion of the plane itself. The airborne MTI radar compensates for this Doppler shift, allowing the radar to detect and analyze objects that are in motion, in spite of the motion of the receiver.

A.6.4 Pulse Doppler Radar

The pulse Doppler radar is similar to MTI radar in that it uses the Doppler shift in frequency produced by a moving target to determine the relative velocity of the target. However, it operates with a much higher pulse-repetition frequency. Use of a high repetition frequency reduces the uncertainties in the radial velocity of the target. However, uncertainties in its range are increased. To overcome the question of range, multiple waveforms having different repetition frequencies are employed.

A.6.5 High-Range Resolution Radar

High-range resolution radar uses a very short duration pulse, producing a range resolution from several meters to a fraction of a meter. This type of radar can determine the profile of an object and measure its projected length in a direction parallel to the direction of the transmitted beam.

A.6.6 Pulse-Compression Radar

Conventional high-range resolution radar using short pulses are often limited in range because of power constraints. At the high powers required for very long range detection, arcing or other power failures occur. Pulse compression overcomes this difficulty by obtaining the resolution of a short pulse using the energy of a long pulse by modulating either the frequency or phase modulation of a long, high-energy pulse.

A.6.7 Synthetic Aperture Radar

The SAR uses the Doppler frequency to provide the equivalent of a cross-range or angle resolution. As mentioned earlier, SAR systems use stored data from a moving antenna to simulate the performance of a large aperture antenna. This type of radar is used for creating maps of the earth's surface.

A.6.8 Inverse Synthetic Aperture Radar

The inverse synthetic aperture radar (ISAR) uses the Doppler shift produced by various parts of the target to obtain high resolution profiling perpendicular to the direction of the transmitted beam.

A.6.9 Side-Looking Airborne Radar

In SLAR, the antenna is situated perpendicular to the host aircraft's line of flight. SLAR generates map-like images of the ground and permits detection of ground targets.

A.6.10 Imaging Radar

Imaging radar is a general category of radar that includes SAR, ISAR, and SLAR systems.

A.6.11 Tracking Radar

Tracking radar continuously focuses on a single target to determine its path or trajectory and to predict its future position. A typical tracking radar might measure the location of a target at a rate of 10 times per second. Before it can track a target, the tracking radar must first find it. Some radar systems operate in a search or acquisition mode in order to find the target before switching to a tracking model (Skolnik 1980). For greater efficiency, some other systems use a separate radar system to locate the desired target. These supplementary radars are called acquisition systems.

A.6.12 Track-While-Scan Radar

Track-while-scan is a type of surveillance radar that can provide tracks of all targets within its area of coverage by measuring the location of targets on each rotation of its antenna. This type of system is also known as automatic detection and tracking (ADT) radar. The visual display output from an ADT system consists of tracks of the targets (i.e., vectors that show the direction and speed of a target) instead of individual detection blips.

A.6.13 Three Dimensional Radar

Conventional air-surveillance radar determines the location of a target in two dimensions: range and azimuth (angle). The angle of elevation of the target (altitude) can also be determined, from which the height of the target can be derived, making it three dimensional. Usually the angle of elevation is obtained by using a vertically rotating antenna in conjunction with a conventional system to measure its range and angle. Modern radar systems do this electronically (Girardin 2009).

A.6.14 Electronically Scanned Phased-Array Radar

An electronically scanned, phased-array antenna can position its beam rapidly from one direction to another without mechanically moving the antenna. This ability allows the operator to switch rapidly between a number of individual targets.

A.6.15 Continuous-Wave Radar

A CW radar transmits and receives at the same time. It, therefore, must rely on the Doppler frequency shift produced by a moving target to separate the weak echo signal from the strong transmitted impulse. This difference can be very large. For example, it is not uncommon for the transmitted signal to be a million trillion (one followed by 18 zeroes) times stronger than the received echo (Skolnik 1980). A simple CW radar system can detect targets, measure their radial velocities, and determine the direction of arrival of the received signal. In order to find the range of a target, however, a more complicated waveform is required.

A.6.16 Frequency-Modulated Continuous Wave Radar

If the frequency of a CW radar is continually changed with time, the frequency of the echo will differ from that transmitted. This difference in frequency is proportional to the range of the target. For practical reasons, the frequency cannot be changed in only one direction (i.e., only increasing or decreasing). Therefore, periodicity is introduced into the modulation and a triangular, frequency-modulated wave form is frequently used (Skolnik 1980). The most common type of frequency modulated CW radar is the radar altimeter used on aircraft to measure height above the ground.

A.7 RADAR PERFORMANCE

The performance of a radar system can be evaluated by the following parameters:

- the maximum range at which the radar can detect a target of a given size;
- the accuracy of the radar's calculations for the target's range and angle;
- the ability of the system to distinguish targets;
- the ability of the system to detect the desired target signal and reject spurious information;
- the ability of the system to define the shape of a target; and
- the availability, reliability, and maintainability of the system.

The maximum range at which a radar system can detect a target depends on the average power of the radar's transmitter and the physical size of its antenna (i.e., power-aperture product). Some radar systems have peak powers of up to 10 megawatts. Phased-array radars have antennas that exceed a diameter of 30 meters. Some OTH radar systems and the United States Space Surveillance (SPASUR) System have antennas with dimensions that exceed 1 mile and could transmit 500-5,000 miles away (Girardin 2009).

In addition to having properties that are favorable for detecting a target at a large range, the maximum range is a function of the sensitivity of the receiving equipment. This sensitivity is determined by the unavoidable noise that appears at the input to the receiver. The receiver is designed to enhance the desired signal while reducing undesired signals.

The size of a target that can be detected by a radar is not always related to the physical size of the object. The measure of the target size as observed by the radar is known as the radar cross section. This size is a rapidly changing function of the aspect of the target relative to the position of the radar unit. Although radar can detect desired objects at large ranges, they also detect echoes from the land, sea, rain, snow, hail, birds, insects, auroras, ice floes, and meteors. These false positive detections can limit the utility of the radar systems. As mentioned previously, the Doppler frequency shift is used to identify moving targets from objects that are stationary.

Detecting targets in the rain is much easier at lower frequencies because the reflected electromagnetic radiation is inversely proportional to frequency. Attenuation by precipitation usually has little effect on the detection of targets except at frequencies above the X-band. Snow and ice particles are not as large a problem as rain for radar systems because ice and snow do not reflect back as much energy (Skolnik 1980). However, as the ice particles, snow, or hail begin to melt in the atmosphere, they create a bright received radar band at an altitude at which the temperature is just above 0°C. The center of the bright band is generally between 100 to 400 meters below the 0°C isotherm (i.e., line connecting equal temperatures). Because raindrops are nearly spherical and aircraft targets have a complex shape, the backscattered energy from rain and aircraft will be affected differently by the polarization of the incident energy. Use of a circularly polarized electromagnetic wave greatly improves the discrimination ability of a radar system. A circularly polarized wave incident on a spherical scatterer, such as a raindrop, is scattered as a circularly polarized wave with the opposite sense of rotation, which is then rejected by the receiving antenna. An aircraft will, however, generate reflected energy with both senses of polarity so that some of the reflected energy will be received by the antenna and then processed by the receiver. Although use of polarized waves will theoretically eliminate the effects of precipitation on radar system performance, some impacts remain because raindrops are not purely spherical and the transmitted wave is not purely circular.

In addition to precipitation, other atmospheric phenomena can also affect the performance of a radar system. For example, the decrease in the density of the earth's atmosphere with increasing altitude causes radar waves to bend (refract) and follow "ducts" around the bend in the earth's curvature. At times, these ducts can lead to blind spots (radar holes) at lower elevations.

Signals from other nearby radars and other transmitters can be strong enough to enter a radar's receiver and produce spurious results. Such interference can be detected by trained operators, but ADT systems may not respond correctly to such interference.

Radar echoes can also be derived from regions of the atmosphere where there are no apparent reflecting sources. These echoes are often referred to as ghosts, or angels. There are two general classes of angels: dot angels, which are point targets caused by birds and insects; and distributed angels, which have substantial horizontal or vertical extent caused by irregularities in the refractive index of the atmosphere.

One of the most common causes of angels is birds, particularly if the bird is located close to the radar so that its apparent cross section is large (i.e., a bird that is nearby can appear on the radar screen to have the same size cross section as a distant aircraft). Also, because birds frequently fly in flocks (particularly during spring and fall migration), their combined cross sections can become very large. It has been estimated that as few birds as eight per square mile can completely blank the screen of a radar console (Skolnik 1980). Although some birds fly at velocities that are below those of concern for an MTI radar system, some birds fly fast enough (18 to more than 50 mph) to produce clutter. Most birds fly at altitudes less than 8,200 feet, with peak numbers between 1,000 and 4,000 feet.

In Alaska as with other parts of the country, bird clutter was a problem early on. There have been recorded instances of geese getting into the jet stream at over 15,000 feet and traveling at speeds of over 100 mph. New software with a special algorithm was inserted in the FPS-117 system to eliminate the problem. Today, birds in flight rarely interfere with system function (Girardin 2009).

As with birds, insects can also pose a problem for some radar systems. High-resolution radar systems can detect a housefly at a distance of 13 miles. Even modest concentrations of insects (one insect in 10,000 cubic meters of air) can cause a moderate level of angel activity and impair a radar's effectiveness. Because most insects are not capable of flight if the temperature is too cold (less than 4.5°C) or too warm (32°C), radars can operate free of insect angels in these temperature regimes. Insect clutter, as well as clutter from birds, can be reduced by use of sensitivity time control (STC). With STC, the gain of the system is allowed to drop off at the end of each pulse to discriminate large echoes produced by nearby clutter.

Radar angels can also be produced by reflections from atmospheric turbulence associated with irregularities in the air's refractive index. These disturbances can be caused by differences in the water vapor, temperature, and pressure (Skolnik 1980). At low altitudes, variations in the water vapor pressure (i.e., humidity) are the major cause of atmospheric angels. Echoes from clear air turbulence are very weak and can only be seen by high-power radar systems.

A.8 COMPARISON OF CIVILIAN AND MILITARY REQUIRMENTS FOR RADAR

Although originally developed for military purposes, radar has found many important civilian applications. In air traffic control, radar is used for the detection of aircraft in flight and for the control of aircraft moving on the airport grounds. Radar is crucial for aircraft navigation and landing aids, and for cooperative beacon systems. Aircraft-borne radar is used not only for navigation but also for detecting and avoiding dangerous weather and terrain (Antebi 1982:176).

At sea, radar is used on ships for piloting, coastal navigation, and collision avoidance. Some of the largest radars are used for surveillance and tracking of satellites. Radar is also used on board spacecraft for landing, rendezvous, and docking and from space it is used for geographical surveys and monitoring the conditions of the atmosphere, weather, sea, and ice. Ground-based radar is used for weather and atmospheric observation and, along with spacecraft radar, the study of extraterrestrial phenomena such as solar behavior and meteors. Radar also has been used in gathering data on the activity of bird and insect populations. Another radar use that can affect the daily lives of people is its use by law enforcement for measuring the speed of vehicles and its use in security systems to detect intruders (Antebi 1982:176).

Most of the advances in radar systems have been in response to military needs. The military uses it widely for surveillance, navigation, and the control and guidance of weapons. Military radar systems fall into three main divisions - land-based, shipborne, and airborne. These broad categories are further subdivided into areas on the basis of operational use of the equipment.

Land-based air defense radars include static, transportable, and mobile systems. These range from large, high-powered ballistic missile detecting radar (i.e., BMEWS), to slightly less powerful early-warning radar for detecting intrusive aircraft. Ground surveillance and battlefield radars include surveillance, tracking, fire control, and weapon locating systems. They can be static, vehicle-mounted, or portable.

Naval radars for surveillance and navigation include shipborne surface search and air search systems, as well as land-based coastal surveillance systems. Shipborne radars are also used for fire control and weapon guidance systems. In addition, there are shipborne radars for interrogation and transponding and for instrumentation and ranging. Because of the sea environment, naval surface surveillance radar systems face particular design problems. Radar range is limited by the height of the antenna allowed on a ship and by the antenna’s weight and size. The result is a compromise for obtaining good short-range surveillance and good data extraction, especially against small targets like submarine periscopes in the clutter of heavy seas. Pulse compression technology is useful in such cases. Another problem is that of sea-skimming missiles or aircraft. The target image tends to be reflected back off the sea surface, causing confusion and assessment errors. To overcome this problem, much higher frequencies have been used, and the radar is integrated with an optical system.

Airborne radars for surveillance include systems designed for early warning, land and maritime surveillance, and navigation to avoid hazardous air turbulence. Passive radar is also used, for example, for picking up emissions from enemy radar-directed missile or gun systems. Airborne fire control radars are used, as are their counterparts on land and aboard ships, for controlling and aiming weapon systems. Of particular note in the early warning category is the system employed in the Boeing E-3 Airborne Warning and Control System

(AWACS) aircraft. The AWACS is an airborne control and command center that directs operations against land, sea, and airborne targets. Looking down on the battle area from high altitudes, the AWACS can observe low- or high-altitude aircraft flying in the area out to a radius of 170 miles. The antenna is contained in a circular radome mounted on top of the aircraft and rotating on the horizontal plane.

A.9 EVOLUTION OF AC&W RADAR SYSTEMS

The types of radar systems used for AC&W in Alaska were identified by a military designation protocol that consisted of a system of letters and numbers. A typical radar designation would be "AN/CPS-6." The designators AN stood for an Army-Navy universal classification system that was established in February 1943 to end confusion over the types of radar being employed by the various military services. The number was associated with the model's design number. The first letter of the three letter combination following the / denoted the housing platform for the device (A = aircraft; C = air transportable; F = fixed, permanent land-based; G = general ground use; M = ground mobile; S = ship-mounted; and T = ground transportable). The second letter indicated the type of device (P = pulsed radar; Q = sonar; R = radio). The third letter indicated the function of the system (G = Fire control; R = Receiving [i.e., passive detection]; S = search; and T = transmitting).

Thus, an AN/CPS-6 was the sixth model of an air transportable, pulsed, search radar. A compilation of radar types used in the AC&W radar systems is given in Table A.1.

A.9.1 Temporary System Radars (pre-Permanent System)

In the postwar 1940s, the temporary system radars in use were of World War II vintage. Search radars usually rotated in a full circle around a central axis. Horizontally mounted height-finder radar focused on the tracked aircraft's reported bearing and then its antenna dish scanned up and down to provide the estimated height of the aircraft.

Three types of radars were used at the interim AC&W sites (known as Lash-up): the AN/TPS-1B, AN/CPS-4, and AN/CPS-5 (see Table A.1). Bell Laboratories developed the AN/TPS-1B, and Western Electric produced it. A crew of two could operate the radar, which could detect bombers at 10,000 feet altitude at a distance of 120 nautical miles (one nautical mile is approximately 6,076 feet). The transmitter sent its pulse at an L-band frequency between 1,220 and 1,280 MHz (Winkler 1997:74). MIT's Radiation Laboratory developed the AN/CPS-4 height finder radar (nicknamed "Beaver Tail"). It operated in the S-band between 2,700 and 2,900 MHz, detecting targets up to 90 miles away. The vertical antenna required six operators. It was 20 feet high and 5 feet wide (Winkler 1997:74). Bell Laboratories along with General Electric developed the AN/CPS-5 radar. General Electric produced it. Designated as a transportable medium-range search radar, it could be operated by a crew of 10. It was designed to provide solid search up to 60 miles at 40,000 feet, and often tracked aircraft as far as 210 miles away (Winkler 1997:74).

TABLE A.1: Radar Types Used in the Aircraft Control and Warning System

Radar Type	Description
AN/TPS-1B	Developed by Bell Telephone Laboratories and produced by the Western Electric Company. Operated by a crew of two in the L-band frequencies. Could detect bombers at 10,000 feet at a distance of 120 nautical miles.
AN/CPS-4	Developed by MIT's Radiation Laboratory. The radar was often used with the AN/FPS-3. Operated by a crew of 6 in the S-band frequencies. Could detect targets at a distance of 90 miles. The vertical antenna was 20 feet high and 5 feet wide.
AN/FPS-3.	Operated by a crew of six. Operated in the S-band frequencies. Could detect targets at a distance of 90 miles. The vertical antenna was 20 feet high and 5 feet wide.
AN/CPS-5	Developed by Bell Telephone Laboratories and General Electric. Produced by General Electric. Operated by a crew of 10. Designed to provide a solid search of up to 60 miles at 40,000 feet, sometimes successful as far as 210 miles away.
AN/CPS-6B	Developed by MIT's Radiation Laboratory. Produced by General Electric. Operated by a crew of 25 in the S-band frequencies. The CPS-6 had two antennas; one slanted at 45 degrees for height-finding capability. Used five transmitters. Initial tests showed the 6B unit had a range of 165 miles with an altitude limit of 45,000 feet.
AN/FPS-3	The AN/FPS-3 was a modified version of the AN/CPS-5 long-range search radar. It was produced by Bendix. The AN/FPS-3B incorporated an AN/GPA-27, which increased the search altitude to 65,000 feet.
AN/FPS-4	Produced and developed by MIT's Radiation Laboratory near the end of World War II. Produced by Zenith post-war, with an updated version produced by the Radio Corporation of America (RCA). Operated by a crew of two. Vertically mounted antenna was 3 feet wide and 10 feet long. Operated at a frequency of 9,000 to 9,160 MHz. Maximum reliable range for detecting bombers was 60 miles at 10,000 feet.
AN/FPS-6	Produced and built by General Electric. Operated in the S-band frequencies, the AN/FPS-6 radar was the principal height-finder radar for the United States for several decades after its introduction.
AN/FPS-7	Developed by General Electric, operated in the L-band frequencies. The radar had a search altitude of 100,000 feet and a range of 270 miles. This radar was significant in that it was the first stacked-beam radar to enter into production in the United States.
AN/FPS-8	Developed and produced by General Electric. Operated in the L band frequencies, designated as a medium-range search radar.
AN/FPS-20	Produced by Bendix. The AN/FPS-20 was an AN/FPS-3 search radar with AN/GPA-27 installed for anti-jamming capabilities. It operated in the L-band frequencies with a range of more than 200 miles.

Source: Winkler (1997:73-83)

A.9.2 Permanent System Radars

The permanent sites used a variety of radar systems, most modified forms of the World War II systems deployed earlier. Over time, various components were added to enhance jamming resistance and to add height-finding capability. Modifications were also made that increased the range of these radar systems. These additions and modifications sometimes resulted in updated model numbers, (e.g., AN/CPS-6B) and sometimes with new designations (e.g., the AN/FPS-3 became the AN/FPS-20 when an anti-jamming component was added).

The centers at Murphy Dome and Fire Island utilized AN/CPS-6B search radars and later AN/FPS-7 search and height finder radars. All of the other sites utilized AN/FPS-3 and later AN/FPS-20 search radar and AN/FPS-6 and AN/FPS-4 height radar (Sturm 1957:33). Table A.1 gives brief descriptions of these radar systems.

MITs Radiation Laboratory originally developed the AN/CPS-6 late in World War II, while General Electric developed and produced the A and B models. The AN/CPS-6 device had two antennas - one slanted at 45 degrees for height finding. The radar used five transmitters operating at S-band frequencies ranging between 2,700 and 3,019 MHz. It required a crew of 25. A component was added in 1954 that improved the radar's range. The 6B had a range of 165 miles with a search altitude of 45,000 feet. The radar and its ancillary equipment were cumbersome, requiring 85 freight cars for its transportation. The Air Force phased out the 6B in the late 1950s (Winkler 1997:75-6).

General Electric also developed the AN/FPS-7 and AN/FPS-8 radars. The AN/FPS-7 had a search altitude of 100,000 feet and a range of 270 miles. Operating in the L-band at 1,250 to 1,350 MHz, it came into use in the early 1960s (Winkler 1997:78). The AN/FPS-7 radar system was one of the first stacked-beam systems to combine both the search and the height-finding capabilities to perform ground-controlled intercept functions. The AN/FPS-8 radar was produced between 1954 and 1958 as a medium-range search radar operating on the L-band at a frequency of 1,280 to 1,380 MHz (Winkler 1997:77-78).

Bendix produced the AN/FPS-3, which was a modified version of the CPS-5 long-range search radar. Improvements to the unit increased the search altitude to 65,000 feet (Winkler 1997:76).

The Radio Corporation of America (RCA) produced the AN/FPS-4 radar. This radar had a vertically mounted antenna that was 3 feet wide and 10 feet long. This radar system only required two operators. Operating at a frequency between 9,000 and 9,160 MHz, its range was limited to 60 miles at 10,000 feet (Winkler 1997:76).

Bendix also produced the AN/FPS-20 unit, which was an FPS-3 search radar with an installed AN/GPA-27, a frequency-diversity (FD) radar to counter electronic jamming. The FPS-20 operated in the L-band frequencies of 1,250 to 1,350 MHz, with a range of more than 200 miles. This radar became the principal unit in the radar defense net by the late 1950s (Winkler 1997:77-8).

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APPENDIX B: SURVEY PARTICIPANT BIOGRAPHIES

Argonne National Laboratory conducted an informal survey of veterans of the AC&W installations to supplement this historical monograph. The survey participants were identified primarily through an Internet site (http://www.bcinet.com/acwrons) conceived and maintained by veterans of these installations. The site can no longer be accessed. Other individuals were identified through word of mouth and other Alaska websites. The survey questionnaire was distributed to interested persons via electronic and regular mail. Veterans were enthusiastic about the questionnaire (and the overall project) and expressed approval of the formal recognition and recordation of the system's history. Data gathered from these surveys has been incorporated into this history. This appendix presents brief biographies of the participants.

Armand G. Biron was born January 16, 1939, in Willimantic, Connecticut. He served in the 720th AC&W Squadron at Middleton Island between November 1959 and December 3, 1960. His rank was Airman 2C, with the position of Radar Operator. After his Air Force service ended in 1969, he continued his education, receiving a B.A. from the University of Connecticut.

Henry Brand was born October 2, 1941, in Rockville Centre, New York. He served in the 744th AC&W Squadron at Murphy Dome from September 1963 to September 1964. His rank was Airman 1C, with the position of Radar Repairman. During his Air Force tour he took USAFI courses. He left the Air Force in 1964.

Waverly Breedlove was born October 1, 1934, in Granville County, North Carolina. He served in the 717th AC&W Squadron at Tatalina from August 15, 1963, to August 15, 1964. His rank was Airman 1C E-4, with the position of Radar Operator. After his Air Force tour he continued his education, receiving a B.S. in Business Administration plus credit hours toward an M.S. at Husson College, Bangor, Maine. He retired from the Air Force in 1978.

James W. Brown Jr. was born July 27, 1934 in Philadelphia, Pennsylvania. He served in the 705th AC&W Squadron at King Salmon from January 1956 to March 1957, and in the 794th AC&W Squadron at Cape Newenham from April 1960 to March 1961. His rank at King Salmon went from Airman 3C to Airman 1C; at Cape Newenham his rank was Staff Sergeant. His position was Inside Wire Maintenance Repairman. During his Air Force service, he completed various correspondence courses and attended Systems Tech Control Technical School at Keesler AFB to change career fields, receiving an M.S. in 1967. After retirement from the Air Force in 1976, he obtained a B.S. in Business in 1981.

Barry Cantor was born December 25, 1945 in Springfield, Massachusetts. He served in the 744th AC&W Squadron at Murphy Dome from November 1969 to November 1970. His rank was Sergeant with the position of Semi-Automatic Data Inserter (SADI Operator) and Senior Director Technician (SDT). After his Air Force service, he continued his education, receiving an Associate Degree from CCAF. He retired from the Air Force in 1992.

Raymond E. Carolin was born March 19, 1948, in Brooklyn, New York. He served in the 744th AC&W Squadron at Murphy Dome from August 1960 to March 1970. His rank was Sergeant, E-4, with positions as Radar Operator, Weapons Control Tech, and Two-Man Control Officer. After his Air Force service, he continued his education up to an M.B.A. After a brief career playing in the National Football League, he became a Special Agent in the U.S. Secret Service under Presidents Nixon and Ford. He left the Air Force in 1970.

Rudy F. Corral was born December 31, 1956, in Richmond, California. He served in the 714th AC&W Squadron at Campion from August 1978 to August 1979. His rank was Senior Airman with the position of Control Technician and Weapons Director Technician. After his Air Force tour, he continued his education, taking management classes at Chapman College. He retired from the Air Force in 1996.

Brian A. Coy was born February 1, 1935, in Gravesend, Kent, England. He served in the 744th AC&W Squadron at Murphy Dome from June 13, 1963, to June 11, 1964, and in the 705th AC&W Squadron at King Salmon from September 2, 1974, to August 1975. His rank at Murphy Dome was Staff Sergeant with the position of Movements and Identification (M&I) Technician; at King Salmon he was Master Sergeant with the position of Operations Training NCO. During his Air Force career, he completed correspondence courses for a Bachelor’s Degree from Auburn University, Montgomery, AL, and completed a CCAF degree in Computer Science. He retired from the Air Force in 1979.

Hubert W. Craig was born May 3, 1933, in Westbourne, Tennessee. He served in the 705th AC&W Squadron at King Salmon from March 1970 to March 1971. His rank was Master Sergeant with the position of NCOIC Dispensary. He retired from the Air Force in 1972.

Charles C. Deits was born March 23, 1931 in Pellston, Michigan. He served in the 709th AC&W Squadron at Fort Yukon from October 1966 to October 1967. His rank was First Sergeant with the position of NCOIC Radar Operations. After his Air Force service, he completed 3 1/2 years of college. He retired from the Air Force in 1970.

C.B. Deyton was born February 6, 1945, in Rutherfordton, North Carolina. He served in the 748th AC&W Squadron at Kotzebue from January to December 1966. His rank was Airman 2C E-3 with the position of Radar Repairman. After his Air Force service he pursued an education in electronics systems maintenance and management through CCAF and ECI. He retired from the Air Force in 1989.

Robert J. Frankenberg was born May 10, 1947, in Chippewa Falls, Wisconsin. He served in the 744th AC&W Squadron at Murphy Dome from June 1968 to June 1969. His rank was Staff Sergeant E-5 with a position as Radar Maintenance Shift Supervisor. He obtained an AA degree in electronics technology during his Air Force service. After he left the Air Force in 1969, he attended DeAnza College, San Jose City College, and San Jose State University, receiving a B.S. in computer engineering in 1974. He was an SEP graduate of the Stanford School of Business in 1986.

William S. Galvin was born September 11, 1935, in Buffalo, New York. He served in the 710th AC&W Squadron at Tin City from September 1958 to September 1959. His rank was First Lieutenant with a position as Officer in Charge of Radar Operations. He left the Air Force in 1960.

Kenneth L. Green was born September 23, 1943, in Bradenton, Florida. He served in the 708th AC&W Squadron at Indian Mountain from August 1972 to October 1973. His rank was Staff Sergeant with a position as Operations Training NCO. After his AC&W tour he continued his education at the NCO Academy, Senior NCO Academy, First Sergeant Academy, and also earned an Associate of Science Degree, legal assistant. He retired from the Air Force in 1988.

Charles W. Greenleaf was born September 19, 1935, in Easton, Pennsylvania. He served in the 718th AC&W Squadron at Unalakleet from March 1962 to March 1963. His rank was Staff Sergeant with a position as NCOIC Radar Maintenance. He retired from the Air Force in 1973.

Thomas A. Gwizdak was born February 1, 1939, in Norwalk, Connecticut. He served in the 711th AC&W Squadron at Cape Lisburne from February 1, 1973, to February 5, 1974. His rank was Master Sergeant with a position as NCOIC Electronics. After his AC&W tour he pursued additional education, receiving an Associate of Arts in instrumentation. He left the Air Force in 1979.

Larry D. Houck was born July 3, 1941, in Salt Lake City, Utah. He served in the 705th AC&W Squadron at King Salmon from June 1974 to June 1975. His rank was Staff Sergeant E-5, with a position in Electronics Maintenance. After his AC&W tour he completed courses in ECI and Small Arms ECI. He retired from the Air Force in 1983.

Richard Lowe was born November 21, 1943, in Dallas, Texas. He served in the 705th AC&W Squadron at King Salmon from December 1974 to December 1975. His rank was Staff Sergeant with a position as Radar Repairman. After his AC&W tour he took correspondence course in TV repair. He retired from the Air Force in 1984.

Fred Mahaney was born October 1, 1938, in West Virginia. He served in the 718th AC&W Squadron at Unalakleet from 1958 to 1959. His rank was Airman 2C with a position as Radar Operator. He left the Air Force in 1960.

James D. Mitchell was born January 23, 1939, in Hempstead, New York. He served in the 712th AC&W Squadron at Northeast Cape from January to August 1959. His rank was Airman 2C with a position as Radar Operator and MARS Operator. After his AC&W tour he took various college courses and management courses. He retired from the Air Force in 1976.

Kenneth R. Owen was born April 28, 1943, in Berkeley, California. He served in the 743rd AC&W Squadron at Campion from January 1963 to January 1964. His ranks were

Airman 3C and Airman 2C with positions as Cook and Baker. After his AC&W tour he earned an Associate Degree in business. He retired from the Air Force in 1984.

Robert C. Prew was born January 14, 1939, in Cherokee, Iowa. He served in the 718th AC&W Squadron at Unalakleet from December 1959 to June 1960. His rank was Airman 2C, E-3, with a position in Radar Maintenance. After his Air Force service, he earned an Associate Degree in electronics from DeVry Technical Institute, Chicago. He left the Air Force in 1960.

Richard W. Rudolph was born April 13, 1939, in Rockford, Illinois. He served in the 711th AC&W Squadron at Cape Lisburne from October 1959 to October 1960. His rank was Airman 2C with a position as Radar Operator and Crew Chief. He left the Air Force in 1962.

Charles A. Sunder was born December 3, 1936, in Jordan, Minnesota. He served in the 719th AC&W Squadron at Sparrevohn from January 24, 1955 to January 9, 1956. His ranks were Airman 3C and Airman 2C with a position as Communications Center Specialist (Teletype and Switchboard Operator). After his Air Force service he graduated from Northwest Electronics Institute in Minneapolis. He left the Air Force in 1957.

David C. Tepe was born September 16, 1938, in Pittsburgh, Pennsylvania. He served in the 1930th AACS as a "guest" of the 718th AC&W Squadron at Unalakleet from April to September 1960. His rank was Airman 2C with a position in TACAN Maintenance. He completed electronics courses during and after his Air Force service, obtaining an FCC First Class Radiotelephone License. He left the Air Force in 1961.

Haskell F. Vanderford was born January 22, 1934, in Lockhart, South Carolina. He served in the 794th AC&W Squadron at Cape Newenham from January 1954 to January 1955. His ranks were Airman 2C and Airman 1C with a position as Administrative Clerk. After his AC&W tour he completed 60 hours of college. He retired from the Air Force in 1972.

Thomas Wikoff was born September 4, 1953, in Bellefontaine, Ohio. He served in the 794th AC&W Squadron at Cape Newenham from February 1974 to February 1975. His rank was Airman 1C with a position as Radar Operator. He completed Alaska Pacific University coursework during his AC&W tour, and after leaving the Air Force, he earned an Associate's Degree from a technical college and attended university courses. He left the Air Force in 1977.