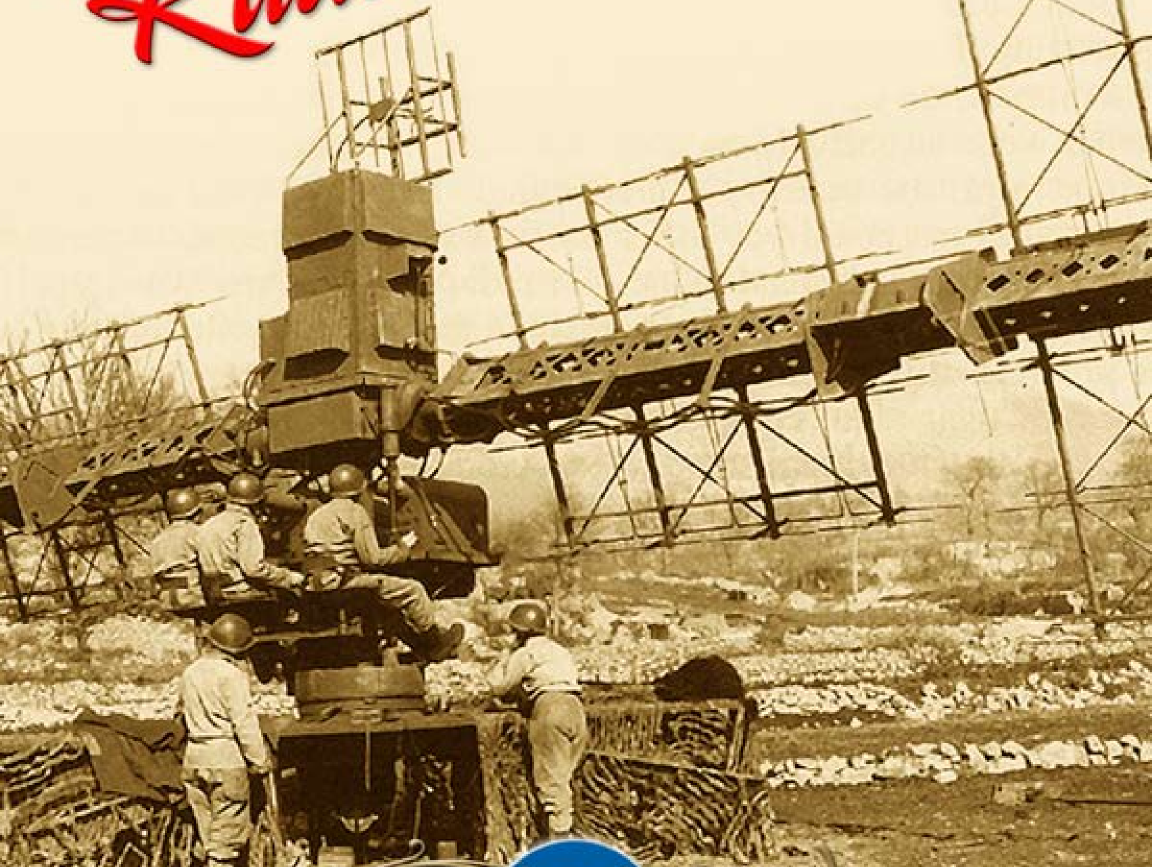
"Radar Contact!"



The Beginnings of Army Air Forces Radar and Fighter Control

RANDALL DEGERING

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About the Author

In 1990, then a captain, Randall DeGering was the only active duty USAF officer to be selected to receive a $1,000 scholarship from the Air Force Historical Research Agency (AFHRA) to research the beginnings of radar development and tactical fighter control before World War II. He first researched the existing technical literature available via universities across the country, this being the pre-Internet era, regarding the "science" of radar development both in the United States and Great Britain. He then visited the AFHRA at Maxwell AFB, Alabama, several times and at personal expense to retrieve many storage boxes of unit histories and review the exploits of various US Army Signal Corps units as they developed the early "art" of radar fighter control. The result of this long and completely off-duty effort was a 170-page research monograph delivered to the AFHRA in 1993. Now, 25 years later, retired Lieutenant Colonel DeGering's research effort is finally available in book form for a much wider audience.

A career air battle manager, he has flown over 2,700 hours aboard the E-3 airborne warning and control system (AWACS) aircraft, conducting real-world theater air control operations around the world. He currently serves at Headquarters North American Air Defense Command as an air defense radar analyst.

Preface

When and how was radar first developed? When was it first employed to direct fighters against approaching enemy aircraft? These two questions began the research that serves as the foundation for this book.

After being selected for an AFHRA research grant in 1990, three years were spent attempting to answer those two primary questions using AFHRA's impressive historical archives collocated with the Fairchild Research Information Center at Maxwell Air Force Base, Alabama. The AFHRA staff have a tremendous amount of information for, and patience with, those new to the world of archival research.

To put this book in its proper context, this is a story that takes place within an Army environment before the beginning of the US Air Force. As the history of radar's research and development unfolds, we will see the Army Signal Corps urgently attempting to develop cutting-edge radar technology. Moreover, as the air defense mission grows, we will see the Army Air Corps struggling to define its new roles and effectively organize itself.

The term *aircraft warning service* (AWS) alludes to an organization of observers dedicated to providing aircraft sighting reports to a centralized center, which then notifies the nearest aerodrome to have its pursuit aircraft immediately take off in hopes of finding the intruder. The term *service* implies a support function, much like the Services of Supply or the Chemical Warfare Service. Unlike most Army services, however, the AWS was composed of both Army Signal Corps technicians and Air Corps aircraft operators. This dual nature would serve as a constant source of frustration to both communities. It is from this mixed environment the first fighter control squadrons emerged.

For an Air Force officer completely unfamiliar with either the development of radar or the history of the Army, several sources formed the foundation of research:

- Concerning the history of radar development, S. S. Swords' *Technical History of the Beginnings of Radar* and *Radar Development to 1945* edited by R. W. Burns were excellent sources.

- For the Army AWS story, the *United States Army in World War II* multivolume "green books" were essential. The volume *Guarding the US and its Outposts*, outlining early air defense efforts, and the excellent, three-volume Signal Corps history series, outlining radar development and the formation of Signal Aircraft Warning companies, proved to be key resources for research.

- For the Army Air Forces viewpoint, the excellent *Army Air Forces in World War II* multivolume "blue books," particularly the first volume, *Plans and Early Operations*, covered early air defense deployments.
- There are many unit histories and reports written during and shortly after World War II, all of which are on file in the AFHRA, to build on these foundational volumes. All that is needed is weeks and weeks to read them!

Overall, this project was a fascinating exercise at its best—a frustrating project at its worst. Research was constantly caught, back and forth, between the Army "green books"—that include a separate Signal Corps series—and the Army Air Forces "blue books." Likewise, since radar air defense and fighter control appear in both green and blue books, neither is covered well in either series.

The hope that one day this book might be published and the story of the beginnings of radar and tactical fighter control would become available and, hopefully, enjoyed by the air battle managers that follow propelled the research and writing. What this book clearly shows is what air battle managers do today has its foundations in procedures and terminology developed by bold and innovative people over 80 years ago. It is also important to know and appreciate our proud fighter controller heritage.

Chapter 1

Testing an Aircraft Defense Concept

Early Air Corps Air Defense Attempts

In 1932, the War Department established four continental field armies to better carry out its United States continental defense responsibilities. First United States Army was charged with defending the United States' eastern seaboard, Second United States Army was responsible for defending the Pacific Northwest region, Third United States Army was to defend the Gulf of Mexico coastline, and Fourth United States Army was to protect the Southwest border.[1]

Also, each of these field armies included a new air district for aviation support. During the 1930s neither the air districts nor the Air Corps had formal systems of aircraft ground control. While the British had developed an ingenious air defense observation system to protect the city of London during World War I, the American Air Corps was not concerned with developing an air defense strategy.

British air defense had reached its apex with the formation of the London Air Defence Area (LADA). In a central control room, a large map was surrounded by plotters wearing headphones and in contact with observation posts surrounding the city of London. Whenever a German zeppelin flew over the country, its position was reported every half-minute to the plotters, who marked out the raider's path on the map. The control room then issued air raid warnings and orders to antiaircraft brigades surrounding the city. Thus, by war's end, there existed a complex air raid warning organization, with the London area well defended. Like all observation networks, however, it was only effective in the daytime. It also suffered from observer errors and was useless in fog or heavy cloud cover. For its time LADA was the most complex area air defense system yet devised, and its fundamental design and operation would be copied by all ground control systems that followed.[2]

The Americans were developing a new air doctrine emphasizing the invulnerability and importance of strategic air bombardment. Consequently the pursuit mission was discounted. Lt Kenneth Walker, an aerial bombardment instructor at the Air Corps Tactical School (ACTS) at Maxwell Airfield, Alabama, stated: "Military airmen of all nations agree that a determined air attack, once launched, is most difficult, if not impossible to stop."[3] Pursuit aviation was considered superfluous. Also, there seemed to be no need for escort aircraft for bomber formations—the "no escort" position.

As strong as the proponents of bombardment aviation were, there were a few pursuit activists. Perhaps the most outspoken of these during the 1930s was Capt Claire Chennault (fig. 1-1), a pursuit instructor at ACTS (fig. 1-2). Chennault described the frustrations of pursuit operations then being employed by the Air Corps:

> The warning system then in vogue was a loose network of spotters who reported vaguely by telephone. . . . Normal orders to defense fighters went something like this: "Enemy bombers reported over Point X at 9 A.M. Take off and destroy them." It would then be 9:15, and X was twenty miles away. When we flew to X and returned after failing to sight any bombers, it was accepted as undeniable proof that fighters could not intercept modern bombers.[4]

Figure 1-1. Capt Claire Chennault, ACTS instructor. (Reprinted from https://commons.wikimedia.org/wiki/File:Capt._C.L_Chennault,_leader_of_The_Flying_Trapeze_poses_in_front_of_a_Boeing_P-12E.jpg.)

Figure 1-2. **Air Corps Tactical School**. (Reprinted from https://en.wikipedia.org/wiki/Air_Corps_Tactical_School#/media/File:A_Concise_History_of_the_U.S._Air_Force_Page_14-1.jpg, Stephen A McFarland, *A Concise History of the US Air Force* [Washington, DC: Air Force History and Museums Program, 1997], 14.)

Later, in his memoirs, Chennault would look back on this early period and remark:

> The speed and armament of the Martin B-10 bomber [fig. 1-3] matched 235 miles per hour and five guns against the 225 miles per hour and two guns of the Boeing P-26 [fig. 1-4], then the standard Army and Navy fighter. The neglected field of fighter tactics, together with the total lack of any means for obtaining information about the enemy and tracking his airplanes, made the contest even that more unequal . . . . Biggest problem of modern fighters was intelligence. Without a continuous stream of accurate information keeping the fighters posted on exactly where the high-speed bombers were, attempts at interception were like hunting needles in a limitless haystack.[5]

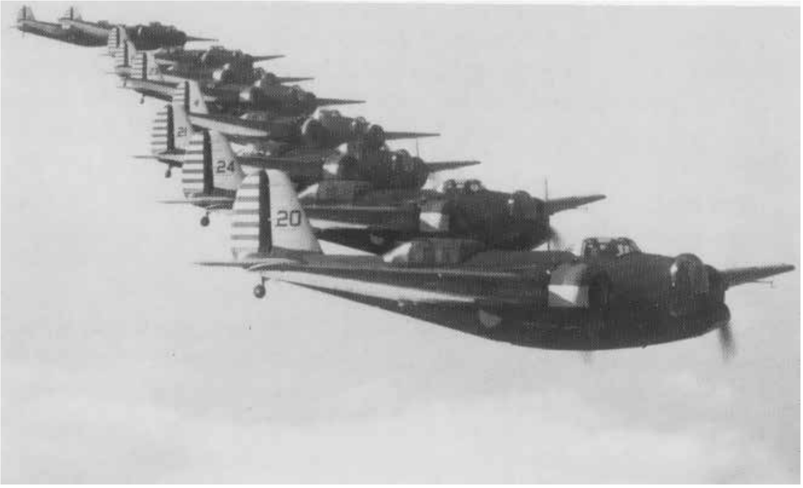

Figure 1-3. B-10 bombers in 1933 maneuvers. (Reprinted from Kohn and Harahan, eds., *Air Superiority in World War II and Korea*. [Washington, DC: Office of Air Force History, 1983], 20, https://media.defense.gov/2010/May/25/2001330267/-1/-1/0/AFD-100525-068.pdf.)

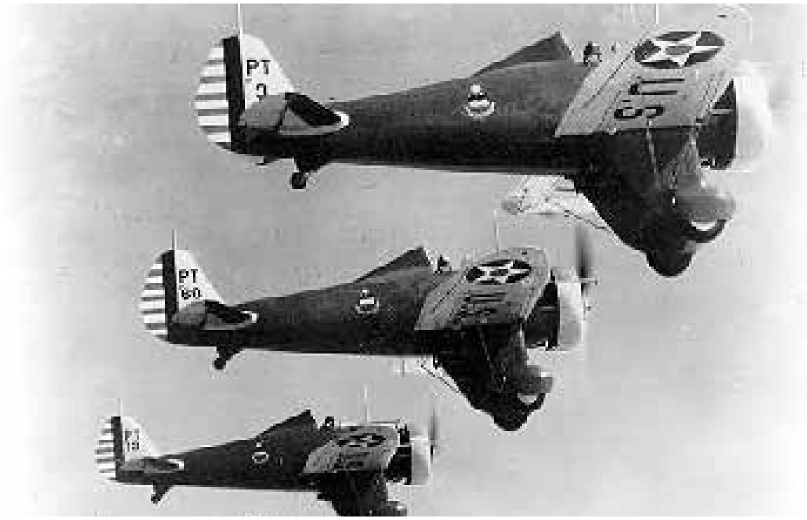

Figure 1-4. P-26 pursuit aircraft in formation. (USAF photo: http://www.nationalmuseum.af.mil/Upcoming/Photos.aspx?igphoto=2000543703.)

Unfortunately for Chennault, the early 1930s Air Corps air defense exercises reinforced the "unstoppable" bomber theory. The 1931–33 Pacific Coast maneuvers conducted from March Field, California (located east of Los Angeles), were described by Chennault:

> Later, "Hap" Arnold, then a lieutenant colonel, ordered squadrons of Martin B-10s from San Diego in an attack on March Field. Defending fighters at March Field took off according to strict military protocol. There was no vulgar scramble. Flights formed over the field and merged into squadrons. Squadrons then circled until the group commander took off and joined them to lead the formation. By that time the bombers had delivered their attack and departed. Only a few independent fighters, stationed at an outlying refueling field, made an interception. They scrambled into the air immediately on receipt of warning without benefit of protocol. Arnold concluded from these maneuvers that fighters would be ineffective in wartime.[6]

Fort Knox, the First Reporting Net Exercise

A joint Army antiaircraft artillery–Air Corps exercise was conducted in May 1933 at Fort Knox, Kentucky, including, for the first time, an attempt at ground control of pursuit aircraft using an organized aircraft reporting network. In the exercise, a line from Indianapolis to Cincinnati divided two warring states, Blue to the north, Red to the south. The Blue's bomber force was based at Patterson Field, Ohio. It included Curtiss B-2s, Douglas B-7s, and Boeing B-9s from March Field and Langley Field, Virginia. The Red air forces, consisting of Curtis P-6s and Boeing P-12s, were stationed at Bowman Field, Kentucky, 26 miles from Fort Knox, representing a rail and supply center to be defended.[7]

This first American attempt at an air defense system was impressive. The intelligence network (or net) consisted of 69 observation posts covering an area of approximately 1,600 square miles. It was shaped in the form of a 120-degree angle facing Ohio, with the apex at Fort Knox. The reporting net was established by the Army's Signal Corps, while observation posts were manned by soldiers from the various ground force branches. Observers had little instruction and experience in identifying aircraft by type and were provided with no instructions for the calculation of altitude or courses. Altitudes were to be simply reported as either "low," "high," or "very high."

During the exercise, reports from these posts were made to the air defense headquarters at Fort Knox, which then immediately relayed the information to the pursuit group operations office at Bowman Field. The group commander would order his aircraft into the air, transmit information as to the latest observation of the enemy forces to his flyers, and direct his aircraft as necessary to keep them between the approaching enemy and their Fort Knox target (fig. 1-5).

Figure 1-5. Maj Carl A. Spaatz directs flights with very high frequency (VHF) radio. (Reprinted from http://media.defense.gov/2010/Sep/23/2001330114/-1/-1/0/AFD-100923-007.pdf, Mauer, *Aviation in the US Army,* 234.)

The results of this first effort at ground control of pursuit aircraft were mixed. Chennault pointed out several of the inadequacies of the system used in the exercise:

> The bands of observation-listening posts were approximately twenty-five miles apart. Hostile bombardment and attack could (and did) change course between bands . . . preventing pursuit from consistently making point interceptions on the enemy's line of flight.
>
> The information net ended at an average distance of about sixty miles from the defended point. Pursuit was forced to make its interception upon information furnished by the inner band of the net. This condition required some unit of pursuit force to be in the vicinity of all the stations on the inner band at the moment the final reports were received. . . .
>
> It did not furnish pursuit with accurate estimates of the type, numbers, course, and altitude of the hostile force. These inaccuracies forced pursuit to search

> much greater areas in space than would have been necessary if accurate reports had been furnished.[8]

Despite these shortfalls, Chennault maintained that "its operation enabled pursuit to make a far greater percentage of interceptions than having ever before been accomplished in any maneuvers."[9]

Using the 1933 Fort Knox exercise as his model, in 1935 Chennault developed his celebrated paper entitled *The Role of Defensive Pursuit*. He reviewed the background of pursuit development and analyzed the causes for pursuit's failure as an effective weapon. He theorized that providing a means for the timely collection and transmission of accurate, continuing information of the hostile force was the key to pursuit's ability to make effective interceptions. The key elements of his theory were:

- First, that an effective pursuit force cannot be maintained airborne at all times.
- Second, that attacking forces must be intercepted at such distance from the defended point to permit destruction of the attackers before they arrive over their target.
- Third, that timely information must be provided to pursuit concerning the approach of the hostile force.
- Finally, that the information must be transmitted to a central authority, evaluated, and acted upon. Changes in strength, course, altitude, and disposition must be continuously reported as they occur.[10]

At this point, probably the single greatest factor in the lack of timely aircraft ground control was the crude state of radio communications technology. Instructors at ACTS realized this deficiency in their texts:

> The difficulty of control during air combat is occasioned by the existence of the very conditions necessary for the accomplishment of flight. The noise of the engine and propeller, coupled with the necessity of continuous movement, almost eliminates the possibility of control through the usual auditory means. Lack of adequate communications is probably the greatest stumbling block in the development of air tactics.[11]

However, in 1935, improved super-heterodyne technology in VHF receivers increased their range and reliability, thereby improving communications between pursuit aircraft and the ground. It is probably fair to conclude that Chennault's theory of ground control of aircraft would not have developed without this new, reliable, means of ground-to-air communications.

With this new technology, Chennault outlined two choices for collecting and disseminating accurate, timely information at frequent intervals:

- observation aircraft or
- a ground intelligence network.

The advantages to aerial observation were offset by three disadvantages:

- observation aircraft were vulnerable to hostile aircraft,
- airborne surveillance might prove costly to maintain, and
- limitations could be imposed by weather conditions.

As envisioned by Chennault, a ground intelligence network appeared to be much more promising. It would use a large number of civilian and military observers located far from the vital area to be defended. Observers would report to a central command post using existing civilian telephone or telegraph equipment. Continuously updated observer information could be transmitted to pursuit aircraft with a powerful command post radio. The large personnel and equipment requirements were not overwhelming disadvantages in Chennault's view.

Chennault also clearly addressed the problems of command and control over this pursuit force. Identifying a fundamental tenet in airpower employment, he stated:

> Action upon information of the hostile aerial force can be directed only by the central authority, who should have under his command and control the means for collecting and evaluating information, and the means for opposing the invasion of the hostile force . . . . The central authority should be the commander of the air force responsible for the aircraft defense of the point or area. It is certain . . . that any division of authority in the central command will result in loss of invaluable time and ineffective aerial operations.[12]

The concept of air defense failed to stimulate the level of intellectual discussion that a more glamourous theory of precision strategic bombardment had attracted. Nevertheless, Chennault's concern for the proper employment of pursuit aircraft did not go unheard. Upon his leaving ACTS in 1935, Chennault was replaced with another pursuit enthusiast—Capt Gordon P. Saville (fig. 1-6). During his tour at

ACTS, Saville became more and more interested in air defense. Unlike Chennault, he did not dispute the dominance of the bomber as an offensive weapon but rather focused purely on the defensive functions of pursuit.

Figure 1-6. **Maj Gen Gordon Saville, first director of air defense**. (Reprinted from Schaffel, *The Emerging Shield*, 44.)

The Florida Air Corps maneuvers of 1935 brought together these various new elements of early warning and ground control for the first time. In a bold change, Saville proposed shifting the command of the pursuit formation from the cockpit to the ground, arousing strong opposition.[13] The commander of the 2nd Wing, Brig Gen H. Conger Pratt, completely supported Saville in a postexercise critique.[14] Pratt concluded that ground control had exercised better command of the P-26 pursuit assets because the ground controllers had more and better information that was not immediately available to the individual airborne pursuit formation commanders. "The entire system is predicated on ground control at all times. When that command is interrupted or assumed by others, the system is immediately susceptible to failure."[15] In response, the ACTS pursuit texts now began incorporating Chennault's and Saville's visionary air defense concept into what was labeled as the aircraft reporting net (ARN) and calling it the "best solution to the problem of defense."[16]

According to this new ACTS doctrine, the ARN was to be organized over an area inside a circle with a radius of approximately 125 miles. Ground observer stations were to be located about every eight miles within this circle and were to report to a control center by direct wire, using a grid coordinate system. As the progress of the hostile aircraft was plotted at the control center, ground control would make decisions concerning the use of antiaircraft artillery (AAA) or pursuit aircraft against the intruders based upon the reported tactical situation. Interceptor aircraft were to be under ground control, who directed them to intercept the attackers.

Responding to the results of the Florida Maneuvers, the War Department issued a new and significant directive on air defense to the four field army commanders in May 1935. It tasked the field armies' air districts to begin preparations for an integrated air defense effort consisting of aviation, AAA, and a new aircraft warning service (AWS) for defense against coastal air attacks.[17] The War Department directive was the first official reference to a formal AWS organization and was probably viewed as a natural successor to the extant Antiaircraft Artillery Intelligence Service.[18]

In May 1936, the Air Corps held another air defense exercise. Flying out of Muroc Dry Lake, just east of Los Angeles, about 300 bombers flew practice bombing missions against the city during the month. Air defense aircraft were launched out of March Field. Recalling those maneuvers, then Flying Cadet James Ferguson (who later became commander of Air Force Systems Command) remembered their difficulties:

> The Muroc Lake maneuvers in 1936 simulated a fighter defense of a metropolitan area—in this case Los Angeles and nearby parts. We, the fighters, were the defenders flying Boeing P-36s. The attacking forces were equipped with B-10 bombers and A-17 attack aircraft [fig. 1-7]. The bombers came in on the attack too high for us to reach them, and the attackers used terrain masking to surprise us on the ground. With no other means of warning, we were caught and treated to a good dose of tear gas which took weeks to shake out of our blankets.[19]

After the Muroc Lake maneuvers, it was now clear that effective warning and control of pursuit aircraft to their bomber targets were critical to the success of air defense. An effective ARN would seem to be the key, but it had never been realistically tested. Could it be made to work?

Figure 1-7. **A-17 attack aircraft**. (Reprinted from Kohn and Harahan, eds., *Air Superiority in World War II and Korea* [Washington, DC: Office of Air Force History, 1983], 24, https://media.defense.gov/2010/May/25/2001330267/-1/-1/0/AFD-100525-068.pdf.)

Fort Bragg, the Proof of Concept

In October 1938, the War Department conducted an ambitious joint Army AAA–Air Corps exercise in eastern North Carolina, around Fort Bragg. For the first time in a major Army exercise, the following air defense ground-control-related objectives would be included:

1. To devise methods for coordinating the action between the Air Corps, AAA, and the Aircraft Warning Service (AWS) in the defense of an air base against attack by "hostile" aviation, including control measures necessary to prevent antiaircraft artillery firing on friendly aircraft operating within the defended area.

2. To test the practicability of organizing an AWS utilizing nonmilitary personnel as observers, as contemplated by frontier defense plans.

3. To test the comparative efficiency of military and nonmilitary personnel as aircraft warning observers.
4. To test the ability of ground observers to detect and determine the types of aircraft flying over their respective positions at various times by day and by night.[20]

For the exercise, Black air forces consisted of three bombardment squadrons, one each of Martin B-10s, Boeing B-17s, and Douglas B-18s, and an attack squadron of Northup A-17s. Based at Langley Field, Black forces were to fly out over the sea and come back over the coastline, representing hostile planes launched from aircraft carriers. Blue forces were to defend the airdrome at Fort Bragg and comprised two squadrons of Consolidated P-30 and a single squadron of Seversky P-35 pursuit fighters, all flying out of Pope Field.

The War Department's planning guidance for the exercise directed the establishment of an AWS over an area consisting of 39 rural counties in eastern North Carolina. Lacking enough Officers' Reserve Corps (ORC) officers to man the "Net," volunteers were identified through the cooperation of local newspapers, the American Legion, and other civic organizations. The few ORC officers who were available manned the 47 US Forest Service fire watchtowers within the grid (fig. 1-8). Local civilian interest was so strong that in practically every instance, each community near a fire watchtower insisted on furnishing additional civilian observers to assist the ORC officers. In fact, in one or two cases, they requested ORC officers not be assigned so they could furnish all the observers.[21]

In addition to the civilian observers, the commercial telephone companies provided tremendous support for the exercise. The Carolina Telephone and Telegraph Company assumed responsibility for coordinating all the activities of the 15 independent telephone companies in the grid area. Telephone company personnel were trained in "flash" procedures for sending priority observation messages to the sector message center in minimum time.

Figure 1-8. **Ground observation watchtower**. (Reprinted from http://www.hampton.lib.nh.us/hampton/history/military/homefront/WWI-Iwatchtower.htm, Official Signal Corps photo.)

An innovation of this exercise was the map room, established for observers and members of the press to keep up with the exercise's situation. A large, 8-foot by 16-foot map was displayed, which used individual lights to indicated each observer station. Loudspeakers were installed so that all might hear each critical "flash" message as it was transmitted by an observation station, while a red light indicated which observer station had just made that report. Pursuit squadron alert orders, launch orders, and interception vectors were heard through the pursuit commander's loudspeaker. Green lights indicated the presence of friendly aircraft observed in an observation grid while flashing green lights indicated the "enemy" interceptions. There was also a speaker sounding the brigade command post on Gaddys Mountain orders directing spotlights and antiaircraft guns.[22]

In his after-action report, the AWS commander was proud of the accomplishment of his military/civilian warning force. During the week of 10–15 October 1938, approximately 1,800 individuals were employed in over 300 observation posts, and not a single "enemy" aircraft passed overhead without being reported. Also, the pursuit commander praised the warning net, saying that it had functioned much better than expected. Finally, the overall defense commander stated, "It has shown that an effective Aircraft Warning Net is necessary to enable pursuit to make interceptions in the daytime."[23]

In a letter to ACTS in 1939, the War Department presented its official views on the exercise. Conclusions reached in Washington relating to ground control of pursuit aviation included:

1. The establishment of an efficient AWS is practicable . . . .
2. An efficient AWS is essential to the effective employment of defending pursuit aviation . . . .
3. Coordination of pursuit and AAA activities during daylight is practicable. The problem of such coordination during darkness has not been solved.[24]

Overall, the employment of pursuit in conjunction with a warning net had proven to be surprisingly efficient. The bottom line from the ACTS was that "the school theory of a coordinated defense, which includes pursuit, antiaircraft artillery, and the interception net . . . was proved sound."[25]

Although overshadowed by the importance of bombardment aviation in the early 1930s, pursuit's acceptance within the Air Corps made steady progress throughout the rest of the decade. To survive the bomber air defense challenge, pursuit aircraft needed ground control. Moreover, clearly, the effectiveness of pursuit was in direct proportion to the efficiency of that ground control's structure and observer corps.

Still in its infancy, this newly-devised concept of an AWS would soon mature into a critical warfighting system—but it would fall to the British Royal Air Force (RAF) to make it happen. While the American Army Air Corps celebrated its modest peacetime exercise success, the British RAF was secretly building its massive operational air defense network while watching a determined Nazi Germany re-arming for war. Moreover, unknown to Chennault and Saville, the British had solved their problems of observation using a new and extremely secret method called "RADAR."

Notes

1. Conn, Engelman, and Fairchild, *Guarding the United States*, 17.
2. Swords, ed., *Technical History*, 176–8.
3. Greer, *Development of Air Doctrine*, 56.
4. Chennault, *The Way of a Fighter*, 22.
5. Ibid.
6. Ibid.
7. Mauer, *Aviation in the US Army*, 415.
8. Chennault, *Role of Defensive Pursuit*, 35–6.
9. Ibid., 36.
10. Ibid., 16–18.
11. Air Corps Tactical School (ACTS), *Pursuit Text*, 166.
12. Chennault, *Role of Defensive Pursuit*, 20.
13. Schaffel, *Emerging Shield*, 14.
14. One of the original wings of General Headquarters Air Force, 2nd Wing was discontinued in 1942 and has no connection with the current 2nd Bombardment Wing.
15. Ibid., 15–6.
16. ACTS, *Pursuit Aviation*, 69.
17. Conn, Engelman, and Fairchild, *Guarding the United States*, 54.
18. Terrett, *Emergency*, 135.
19. Kohn and Harahan, *Air Superiority*, 26.
20. ACTS, Report of the Defense Commander, 1.
21. ACTS, Annex 3, 7.
22. Ibid, 8.
23. ACTS, Report of the Defense Commander, 15.
24. ACTS, Annex 2, 2.
25. ACTS, Study of the Reports, 6.

Chapter 2

The Invention of Radar

American "Radio Position Finding" Research and Development

The basic principle of radar detection is almost as old as the subject of electromagnetism itself. Heinrich Hertz, in 1886, tested the theories of James Maxwell and demonstrated that radio waves could be "reflected" by metallic and dielectric bodies. Guglielmo Marconi recognized the potentials of short waves for radio detection and strongly urged their use in 1922 but was apparently unsuccessful in gaining support for this idea. Also, during the 1920s, much discussion occurred concerning the use of radio detection methods aboard ships to avoid collisions, but these topics received limited government interest.[1]

The first detection of aircraft using experimental continuous wave (CW) equipment was in June 1930 by Lawrence Hyland, Albert Taylor, and Leo Young of the US Naval Research Laboratory (NRL) near Washington, DC (fig. 2-1).[2] It was made accidentally while testing a radio direction-finding device located in an aircraft parked on the grounds of nearby Bolling Field. While receiving signals from a transmitter located two miles away, Hyland noticed the transmitter's signal seemed to appear from other directions whenever random aircraft happened to pass overhead their parked airplane—in effect, reflecting the transmitter's signal back to Hyland's receiver. This discovery stimulated a more deliberate investigation by the NRL, but the work continued slowly due to the lack of official support and funds from the US government.

However, by 1932, equipment had been developed by the NRL that could detect aircraft at distances up to 50 miles. At this point, it is important to note, however, that CW equipment could only detect the presence of a distant target. The problem of determining a target's position—that is, its bearing and range—was a difficult one and could not be readily solved with then-current technology. The NRL's work on aircraft detection with CW signals was kept classified until 1933, at which point several Bell Telephone Laboratories engineers reported the detection of aircraft by radio means during other experiments. Realizing the confidentiality of their work had now been compromised, the NRL then disclosed its work.[3] A US Patent (No. 1981884) was granted to Hyland, Taylor, and Young for "A System for Detecting Objects by Radio" on 27 November 1934.

Figure 2-1. **US Naval Research Laboratory**. (Reprinted from https://commons.wikimedia.org/wiki/File:US_Naval_Research_Laboratory_in_1944.png, US Navy photo.)

The limited ability of CW equipment to be anything more than a trip wire, providing only general range data about a target, explains the little official US enthusiasm that existed for future research. Having spent three years on this method, the NRL also recognized this limitation and realized that to obtain accurate target position information, energy had to be transmitted in pulses that could be timed and measured. Thus, a new NRL effort was started by Robert Page in spring 1934 on pulsed energy transmission and measurement.

After nearly two years of working and reworking his designs, in April 1936 Page's pulsed transmission equipment first successfully detected an aircraft at about 2.5 miles of range.[4] It operated at 28.2 megahertz, with a peak power of over 3 kilowatts, a pulse width of 5–7 microseconds, and a pulse repetition frequency of about 1,800 cycles per second. Further improvements were made, and by November 1936, aircraft as far as 36 miles were being successfully detected (fig. 2-2).

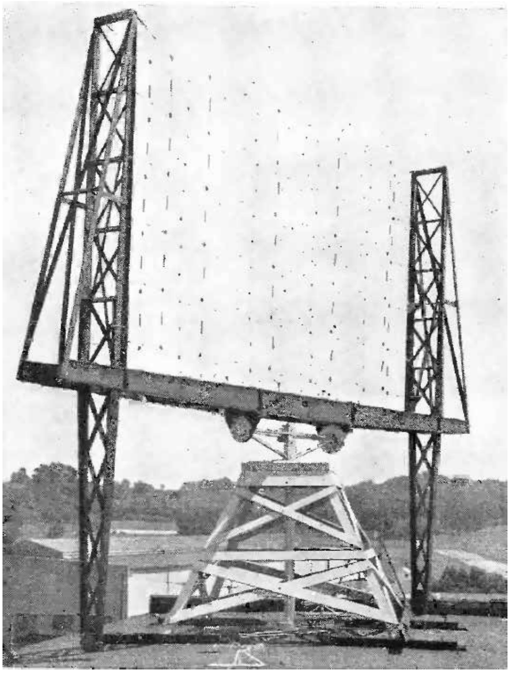

Figure 2-2. **Early Naval Research Laboratory radar**. (Reprinted from https://commons.wikimedia.org/wiki/File:Early_radar_antenna_-_US_Naval_Research_Laboratory_Anacostia.jpg, a 1945 issue of *Radio News*.)

Throughout the course of this naval radio detection research during the 1930s, the US Army Signal Corps maintained a similar interest. The Corps was responsible for developing all Army signals equipment, such as radio and wire communication sets, and for training all Signal Corps personnel to operate such equipment. The beginning of serious Signal Corps work in pulsed detection apparently resulted from a visit to NRL in January 1936 soon after Page's first pulsed detection demonstration.[5] While research at NRL was conducted over a broad spectrum of interests, the efforts of the Signal Corps Laboratories (SCL) at Fort Monmouth, New Jersey, were geared toward the more narrow development of specific pieces of Army equipment. Thus, while there was no additional funding allocated by the War Department, by May 1936 "pulsed-echo detection" research had received a high priority at the Army lab.

On 14 December 1936, equipment loaded on two trucks (one for the transmitter and one for the receiver) set out for a site near Princeton to monitor traffic in and out of Newark airport, parking one mile apart. There SCL engineers saw the device record the echoes of the pulses directed toward the flight path of arriving and departing airliner traffic. Crude and experimental as it was, and only able to track aircraft out to seven miles, it was, nevertheless, the first successful Signal Corps pulse radar.[6]

The turning point for US radar development occurred on 18 May 1937, when the Secretary of War, Hines Woodring; the Chief of the Air Corps, Maj Gen Oscar Westover; and several US senators and representatives attended a classified night demonstration held at the SCL. Successfully detecting 13 out of 15 aircraft travelling above 6,000 feet, the new detection equipment was used to illuminate each target aircraft using a searchlight. Impressed by this amazing achievement, Secretary Woodring wrote a congratulatory letter to both the Chief Signal Officer and President Franklin Roosevelt and asked if $200,000 (equal to $3.5 million in 2018 dollars) would be sufficient for further research.[7] This experimental set was soon to become the US Army's first operational radar set, the Signal Corps Radio (SCR) 268 (fig. 2.3). A mobile, short-range, height finding set, the SCR-268 was designed primarily to be used as a searchlight director and AAA gun-laying radar.

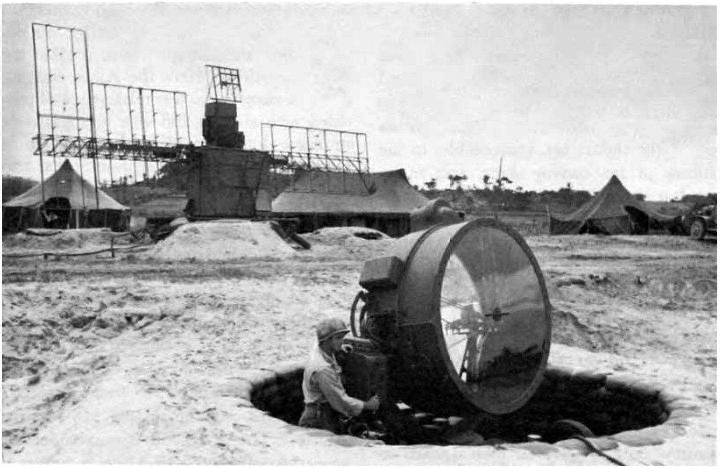

Figure 2-3. **SCR-268 short-range radar**. (Reprinted from George Raynor Thompson, Dixie R. Harris, Pauline M. Oakes, and Dulany Terrett, *US Army in World War II: The Technical Services: The Signal Corps: The Test* [Washington, DC: Office of the Chief of Military History, 1957], 376, http://www.history.army.mil/html/books/010/10-17/CMH_Pub_10-17.pdf.)

The day after it had been successfully demonstrated, the prototype SCR-268 was disassembled and secretly moved from SCL to nearby Fort Hancock on Sandy Hook, New Jersey.[8] Its antenna was mounted atop an adjacent lighthouse station on the beach at Navesink, overlooking the heavily traveled air routes crossing New York Bay into Newark and New York City. From here, redesigning and testing continued. The 62nd Coast Artillery Regiment (Antiaircraft), also stationed at Fort Hancock, not only guarded the secret site but helped operate the unique equipment. The unit represented the typical skilled enlisted man who would eventually actually operate the new detector, and their efforts to resolve its many technical problems proved invaluable.

Also impressed with the demonstration was Brig Gen Henry "Hap" Arnold, assistant chief of the Air Corps. He proposed, in June 1937, an operational specification for a long-range detection and tracking radar specifically for Air Corps use, capable of detecting aircraft at a range of 50 miles, later increased to 120 miles.[9] The next month, the technical characteristics required by the Air Corps for this new long-range, early warning radar set were formally approved by the Army Signal Corps. And by October 1938, a contract was signed with the Westinghouse Electric Corporation to assist the Signal Corps with additional pulse radar research and development.

Greater detection range was the prime concern of the Air Corps, rather than greater equipment mobility, which was desired by Army ground antiaircraft crews. Therefore, by June 1938, the work at the Fort Hancock site had now been split into two camps: one completing the work on the short-range SCR-268, and one beginning research on a new, long-range, early warning prototype—the SCR-270, a trailer-mounted version, pulled by a truck, and the SCR-271, a fixed-site version of the SCR-270. By August, a preliminary SCR-270 model detected a bomber at 75 miles.[10]

In November 1938, the Army service tests began on the SCR-268 at Fort Monroe, near Langley Field, Virginia. While not as accurate as hoped for, during one night service test, a target Martin B-10 bomber was blown off course by 100 mph winds without realizing it. After reaching 60 miles out to sea, the pilot surrendered to the urgent warnings of the SCL engineers, who had him exactly plotted on their oscilloscope and who guided the aircrew safely back to their field—the first recorded save of an aircraft by radar![11] About the SCR-268, it was said that:

> Nobody liked it very much but everyone wanted it badly. . . . Its performance was satisfactory for pointing searchlights, although it was considered too bulky. It was not quite accurate enough for precision [AAA] gun laying, but it was the only available American set that permitted an effective antiaircraft barrage through overcast. Its power gave it greater range than necessary for either of these . . . purposes, but not quite enough . . . for . . . early warning.[12]

The SCR-268 transmitted on 205 megahertz, producing wavelengths nearly nine feet long, and thus requiring a huge antenna. Having reduced the antenna size down as far as possible, the SCR-268—with its limited mobility—was declared wartime ready for US Army operational use in May 1939.

In December 1939, again with Woodring and General Arnold observing, the mobile, long-range SCR-270 set began its certification tests at Fort Hancock. Six months later, in May 1939, the US Army officially adopted it as its first early warning pulsed-echo radar set.[13] Originally, this method of detecting aircraft by radio means was labeled by the Army as "radio position finding" or RPF.[14] In addition, for the next several years, for security reasons, it would also be referred to as "Radio-B" or the mystifying nickname "Derax." Later, however, in January 1942, the US Navy officially began designating its detection systems with the name "RADAR" for radio detection and ranging, and this new name was soon universally adopted.[15] Across the Atlantic, however, it was a very different story. For by this time, the British Royal Air Force (RAF) was already far ahead of the work in radar research and development (completely unknown to their Allies) and were desperately hurrying to finish the world's most advanced, radar-based air defense system—before it was too late.

British "Radio Direction Finding" Research and Development

Radar emerged more rapidly in the United Kingdom in the mid-1930s because of the country's vulnerability to direct air attack from the nearby continent. By 1934 the British knew that Hitler was building up Germany's air force, the Luftwaffe, and was aiming for nearly 4,000 bombers—easily capable of overwhelming the RAF's 600 fighters.[16] Also, the summer RAF air exercises of 1934—virtually identical to the US Air Corps exercises conducted in 1931–1932—underlined the fact that Britain was almost completely defenseless against air assaults.

The RAF pilots simply could not find incoming bombers in the vast sky. During daylight raids, 50 percent of the "hostile" bombers were not intercepted.[17] A realization of this fact by RAF officers, Air Ministry civil servants, and politicians generated mounting pressure to develop a solution, and very quickly.

In January 1935, the Air Ministry hosted the first meeting of the Committee for the Scientific Survey of Air Defence, chaired by Henry Tizard, then also chairman of the government's Aeronautical Research Committee. The possibility of using electromagnetic radiation to damage aircraft or to incapacitate its aircrew was discussed at this first meeting. An unpredictable Scotsman named Robert Watson–Watt, superintendent of the Radio Research Station, was asked by Tizard's committee to research this futuristic option (fig. 2.4).

Figure 2-4. **Dr. Robert Watson–Watt**. (Reprinted from https://commons.wikimedia.org/wiki/File:Robert_Watson-Watt.jpg, Air Ministry, United Kingdom, photo.)

Watson–Watt, in his famous February 1935 memorandum entitled "Detection and Location of Aircraft by Radio Methods," concluded that a "death ray" was not feasible but that shortwave radio illumination, using a pulse method, might be used for the detection of aircraft. Completely unfamiliar with the NRL's then-secret research on this very same concept, his memorandum urged that Britain ring its shores with "an invisible curtain" of radio waves:

> So, said the memorandum, you must set up, in the region through which [an aircraft] must pass to reach us, an invisible curtain of short radio frequency waves. He cannot prevent some small faction of this radio energy being reflected back, more or less toward its source, as a radio "echo" from his craft. If we pick up even a minute fraction of this echo, we can make it tell us a lot about him . . . so, said my memorandum in effect, give us the job and we will finish the tools, and we shall be surprised if we can't track a single aircraft from 200 miles away.[18]

Events moved rapidly after this memorandum was issued. During the same month, as a test, Watson–Watt's team positioned a receiver near the British Broadcasting Company's shortwave station at Daventry, 75 miles northwest of London, and flew a RAF Hadley Page Heyford bomber up and down the transmitter's beam. The objective was to attempt to detect any fluctuations in the receiver's signal caused by reflections from the bomber, which would show as "blips" on an oscilloscope. This was the same effect noted earlier by the NRL, which had just been granted its now unclassified CW radar patent—too soon to have come to the attention of the British scientific community. The bomber test was a success, detecting the aircraft out to a range of about eight miles.[19] This satisfied RAF Air Vice-Marshal Sir Hugh Dowding, the Air Ministry's Air Member for Supply and Research, who then granted £12,300, equal to almost $800,000 in 2018, for a large-scale experimentation during the rest of 1935.

In May 1935, in a race against time, Watson–Watt's team (numbering only six people, and working in utter secrecy) moved their operations to Orford Ness, an isolated, sandy isthmus on the wind-swept eastern coast of England. The focus now was on developing a working pulse transmitter, operating at a low frequency of 6 megahertz, with a wider pulse length of about 15 microseconds, at a pulse repetition frequency somewhere between 50 and 1,000 cycles per second, and having a peak pulse power of about 50 kilowatts. The brilliant team was soon successful.

By the end of the month, the first pulse radar echoes were being successfully bounced off the ionosphere by Watson–Watt's team—very close to Page's original radar specifications—except for the much higher power needed to cross the English Channel—and secretly accomplished almost a year earlier than Page's first successful pulse radar tests at NRL in April 1936.

By July 1935, RAF aircraft were being tracked from Orford Ness out to a range of 34 miles.[20] The number of aircraft that were flying in formation was also being correctly counted. One of the test engineers would later remember those research flights and write:

> Security was of the maximum category. We did not advertise that any secret work was in progress by enclosing the site in barbed wire with sentries on the gate. The pilots were not told anything of the work. It was at the time when the pilots handed in their flight logs that we had to be extremely careful what we said. We wanted to be as open as possible and talk with the chaps who were working with us. On one occasion, we realized that we asked one question too many, and had to alter the line of the conversation very quickly but smoothly. It became evident that the slip had not been noticed and so we relaxed once again.[21]

This experimental pulse method was labeled by Watson–Watt's team as "radio direction finding" or RDF. This name was considered suitably confusing since it suggested an aircraft navigation method instead of being a method of aircraft detection.

Thus, in September 1935 with the secret RDF research now moving at a rapid and successful pace, Watson–Watt drafted a plan to the Tizard committee formally proposing that a "chain" of early warning RDF stations be built along the eastern coast of England to provide detection and tracking of enemy aircraft off the British shores. Even though no actual prototype RDF station yet existed, the Air Ministry approved the proposal based upon Watson–Watt's record of success, authorizing £60,000, equal to $4 million in 2018, for five initial RDF stations along the coasts of Dover to protect the air approach to London.

Having suggested the original concept of radar only 10 months before, Watson–Watt's team now had to construct a series of actual, working coastal early warning stations, entirely based upon the new "art" of RDF, and all in hopes that it could be done before it was too late. The race was on.

Notes

1. Swords, *Technical History*, 52.
2. Skolnik, *Introduction to Radar*, 9–10.
3. Burns, "Background to Development," in Burns, ed., *Radar Development*, 23.
4. Swords, *Technical History*, 107.
5. Coulton, "Radar in the U.S. Army."
6. Terrett, *Emergency*, 46.
7. Swords, *Technical History*, 115–6.
8. Terrett, *Emergency*, 123.

9. Ibid., 48.
10. Ibid., 123.
11. Ibid., 127.
12. Ibid., 127–8.
13. Ibid., 129.
14. Thompson, Harris, Oakes, and Terrett, *Test*, 62.
15. Terrett, *Emergency*, 41.
16. Deighton, *Fighter*, 121.
17. Swords, *Technical History*, 82–4.
18. Watson–Watt, *Pulse of Radar*, 56–8.
19. Skolnik, *Introduction to Radar*, 11.
20. Strebeigh, "How England Hung the 'Curtain'," 125.
21. Carter, "Personal Reminiscence: RDF [radio direction finding] and IFF [identification-friend-or-foe]," 154.

Chapter 3

The RAF's Fighter Control System

Air Ministry Experimental Set 1 at Bawdsey Manor

In May 1936, Watson–Watt's radar team was moved from Orford Ness to Bawdsey Manor, near Felixstowe and 60 miles northeast of London, perched high atop the cliffs of England's eastern coast, to supervise the building of the first operational radar station.[1] Assembling a team of brilliant young scientists from various British universities, they would continue to work and conduct training at the Manor until the start of World War II (fig. 3-1). In August, Henry Tizard called a conference at Biggin Hill, a Royal Air Force (RAF) airfield southeast of London, with three RAF officers and a civilian engineer.[2]

Figure 3-1. **Bawdsey Manor on the English coast**. (By permission from John Fielding, https://www.flickr.com/photos/john_fielding/14924955295.)

With Air Ministry approval, Tizard told this small group that a new secret capability now existed for detecting approaching bomber raids at ranges of 100 miles or more. Proposing that a fighter could be directed from the ground to intercept such raids, he tasked his team to develop the procedures necessary to control such interceptions. As a beginning, he proposed the "Principle of Equal Angles" be used to establish interception geometry. The angle of fighter interception was calculated from an isosceles triangle consisting a baseline between the fighters and approaching enemy bombers (or enemy fighters, for that matter), and a second line formed from the bombers' detected position and apparent heading to target. The third line of the triangle was the fighters' line of interception from their position to a point of interception with the bombers. Ground controllers would calculate the angle between the baseline and the bombers' heading to target. An "equal angle" or "Tizzy angle" would be the course or "vector" directed by the controllers to the fighters. The point at which the fighters' vector line crossed the bombers' heading line would be the predicted interception point.[3]

For the first few months, the four men attempted to develop manual rulers to help calculate the required interception angles. When nonmaneuvering interceptions became easy, the targets were ordered to "jink" or change their course of flight. Now the interceptions became complex, as the time delay between radar detection and position plot made it difficult to accurately determine the raid's new heading and thus the three new angles involved. The fighters' original course had to be altered in mid-flight, and the ground controller had to work fast.[4]

During one trial, as one of Tizard's team members was controlling, the Biggin Hill station commander, Wing Commander Eustace Osborne Grenfell, saw that a mistake had been made in computing the fighter's interception heading. There was no time to work out a new Tizzy angle. Estimating by eye, he voiced a snap correction—and the pilot made the interception! Impressed by his quick actions, Tizard reasoned an experienced fighter controller could do much of the controlling almost by instinct rather than through using formal calculations. The scope of Tizard's experiments was thus widened, with more aircraft and more controllers. Over the next year, Tizard's team would determine the best methods for controlling and would learn that the best controllers could manage up to four interceptions simultaneously.[5]

By September 1936, only one radar transmitter tower at Bawdsey Manor had been constructed. Due to shortages, work was going extremely slowly. The station's first air exercise was to be conducted with the RAF that month—and it was a disaster, adding to the frustration. Watson–Watt was concerned; Tizard was furious. The work continued. Six months later, in March 1937, nearly a year and a half after its approval, this first radar station, designated Air Ministry Experimental Set (AMES) 1, was handed over to the RAF for operational use. Flying as many as 10 bombers a day against AMES 1 throughout the month of April, the RDF exercises were judged to be successful. Aircraft were routinely plotted out to 80 miles, and there was even one detection at 112 miles (fig. 3-2).[6]

Figure 3-2. **Radio direction finding (RDF) operator plotting aircraft on the scope**. (Reproduced from http://media.iwm.org.uk/iwm/mediaLib//39/media-39665/large.jpg, Imperial War Museum [IWM] photo.)

The overall air defense structure, called "Chain Home," was planned to have a transmitting station every 20 miles, no more than two miles from the eastern coastline, with every other station having a receiver, as well. Each transmitter used an enormous 350-foot steel tower (transmitting pulsed signals using one of four frequencies between 22–30 megahertz, with a peak power of 200 kilowatts), while receivers used 240-foot wooden towers to minimize signal reflection. The system was able to detect the approaching raid's altitude, and detection range was eventually 120 miles.[7] By July 1937, a second Chain Home station had been opened at Dover, and by August, a third station was operational at Essex. The first five RDF stations making up the new Chain Home system were declared operational (figs. 3-3 and 3-4).[8]

Figure 3-3. **Chain Home steel and wooden radar towers**. (Reproduced from http://media.iwm.org.uk/iwm/mediaLib//36/media-36281/large.jpg, IWM photo.)

Figure 3-4. **RDF station reporting aircraft to Fighter Command**. (Reproduced from https://upload.wikimedia.org/wikipedia/commons/8/88/Royal_Air_Force_Radar%2C_1939-145._CH15331.jpg, IWM photo.)

The Control and Reporting System

As each RDF station was successfully built, the RAF next turned to devising a control and reporting (C&R) system to report the presence of enemy aircraft and to control the fighters sent up to intercept them. Overall tactical command of fighter assets was vested in HQ Fighter Command, at Bentley Priory in Stanmore, a north London suburb. The RAF commander-in-chief was now Air Chief Marshal Sir Hugh Dowding who had granted the original funds for AMES 1 back in 1935. Later, the C&R system would also become known as the "Dowding System" (fig. 3-5).[9]

Figure 3-5. **Air Marshal Sir Hugh Dowding**. (Reproduced from https://en.wikipedia.org/wiki/Hugh_Dowding#/media/File:Hugh_Dowding.)

In short order, the entire British Isles had been divided into four regions, each protected by an RAF fighter group. Each fighter group region was further subdivided into group sectors. Tactical control of fighters in each group area was delegated to fighter group headquarters. Once fighters were airborne, they were controlled directly by the appropriate group sector. Each sector headquarters, group headquarters, and the Fighter Command headquarters had an operations room in which all air activity within each respective area could be plotted and controlled.[10]

As each RDF station reported aircraft positions simultaneously to Fighter Command, a means of resolving target duplications had to be found. "Filtering" was the name given to this process. An experimental filter room was set up at Bawdsey for the August 1937 Fighter Command exercise to sort out the plots passed by the three Chain Home stations. The filter room was then to "tell" the filtered plots to Fighter Command, and it later became installed as part of Fighter Command headquarters. Filtered plots could then be conveyed down to the subordinate group sector operations rooms for tactical fighter control once aircraft were airborne.[11] Properly correlated target plots were then manually placed on general situation maps in the sector operations rooms by plotters wearing headsets and using "croupier's rakes" to move the plots of friendly and hostile aircraft on the map. On a dais above each map sat the sector controller. At first, these officers were pilots who had flown in World War I (fig. 3-6).

Figure 3-6. **Operations room**. (Reproduced from https://upload.wikimedia.org/wikipedia/commons/7/76/Radar_and_Electronic_Warfare_1939-1945_CH13680.jpg, IWM photo.)

As readiness or aircraft scramble commands were received at each sector, sent down by the group commander, they were posted for all to see. Readiness states ranged from "2 hour" where pilots were allowed to be anywhere on the field, to "1 hour," to "30 minutes," to "15 minutes" as the imminence of each threat was assessed. "Come to readiness" was the call for pilots to run to their aircraft and be ready to take off within five minutes.

Finally, "Scramble!" was the order to take off, usually made with a flare pistol. After a mission, squadrons were often "released" so they could stand down for maintenance and aircrew rest.[12]

When the group controller ordered a squadron to readiness, and the fighters scrambled, the sector controller would then speak to the flight leader using one of four radio-telephone (R/T) sets available to him. It was up to the sector controller to provide the flight leader what course and altitude to fly as well as the enemy's current position, altitude, course, and number. Controllers used amplitude modulated (AM) radio transceivers having a range of 35-40 miles at 15,000 feet and were vulnerable to significant interference, including British Broadcasting Corporation (BBC) radio broadcasts. VHF radios were eventually introduced in late 1940, which had a better range of 100 miles at 20,000 feet (fig. 3-7).[13] Amazingly, almost all basic R/T code words used today for communications between controllers and pilots are the very same phrases invented by the RAF during this time.

A report reviewing the annual RDF exercise held during August 1937 outlined the C&R system's operation:

> Information required by the three Groups will be obtained by at least 15 [RDF] stations, the observers at which, in time of high raid density, will tell plots at a high rate. This information is to be filtered and passed accurately and speedily to Groups and Sectors simultaneously. This means that on the average, when stations are all bringing in raids, the Group teller will have to tell information receiver from five stations and will therefore have to tell information at five times the rate of the observers. . . . A Sector requires information accurately and speedily at the rate of one plot per minute per raid. If each Sector can handle even four simultaneous raids, plots must be received at the rate of four per minute.[14]

With four groups totaling 27 sectors, it is evident why one of the most acute problems for a sector controller was receiving timely plot data on which to base interception efforts. It also demonstrates why careful selection of RDF operators, plotters, and filterers was essential.

It should be noted that a significant proportion of the personnel employed at RDF stations and operations rooms were from the Women's Auxiliary Air Force (WAAF). When three WAAF typists assigned to Bawdsey Manor had been trained to read and tell cathode ray "A-scope" radar returns, it became apparent that women adapted in many ways better than men to this tough and tiring work.[15]

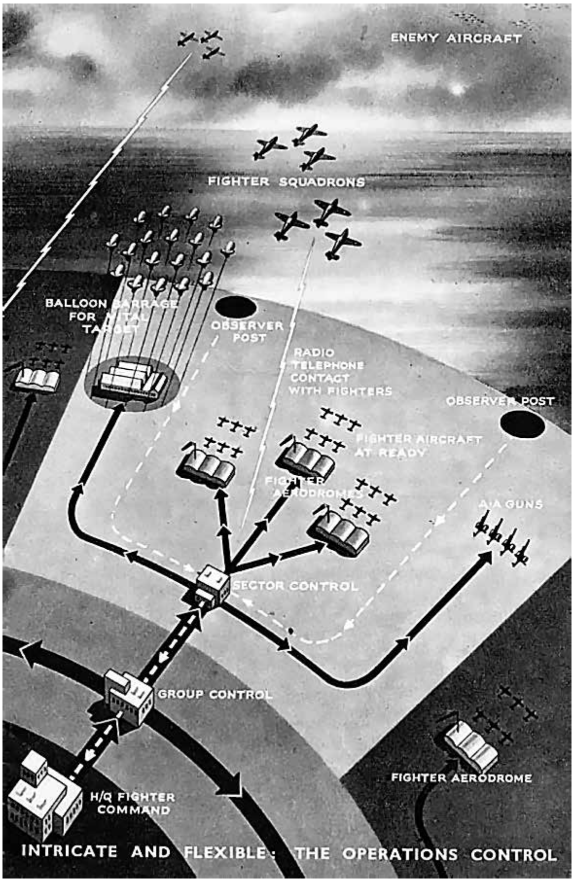

Figure 3-7. The Dowding C&R system. (Reproduced from 1941 UK Air Ministry pamphlet, https://upload.wikimedia.org/wikipedia/commons/3/36/Operations_Control_from_1941_pamphlet.jpg.)

Finally, after four furious years and the expenditure of £10 million (equal to almost $680 million today), the Chain Home network, consisting of 29 RDF stations, started a constant watch of the lengthy eastern English coast on Good Friday, April 1939 (fig. 3-8).[16] As it was clearly impossible to hide Chain Home stations with their massive 350-foot steel towers, the Germans naturally became quite interested. Intrigued, the chief of the Luftwaffe signals service soon deployed the *Graf Zeppelin*, loaded with many high-frequency (HF) receivers—a flying radio laboratory. Launched at the end of May 1939, the airship crossed the English Channel and approached the coast of England.[17]

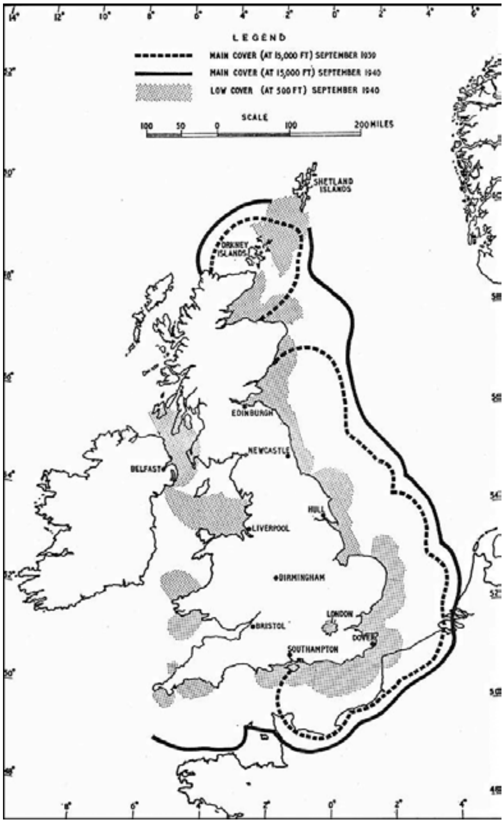

Figure 3-8. **Chain Home coverage, 1939 and 1940**. (Reproduced from https://upload.wikimedia.org/wikipedia/commons/d/de/Chain_home_coverage.jpg.)

Detected by the Home Chain station at Canewdon, the biggest imaginable blip appeared on their A-scopes, moving slowly and majestically across the screen. The RAF, delighted to receive such a jumbo practice run at German taxpayers' expense, followed the airship mile by mile as it slowly turned and began its northern run up the English coastline. As the theater was quite foggy, the airship reported its estimated position along the coastline back to its headquarters in Frankfurt, Germany. The airship's intercepted message caused much amusement at HQ Fighter Command, for the navigator's reported dead reckoning was nine miles off his true course as tracked by Chain Home—he was flying over English territory itself![18]

After completing its signals collection run, the airship continued north to Scotland, then turned east for home. All the crew received for their efforts, however, was only loud static. Since no voice transmissions were ever detected, the actual meaning of these huge "radio" towers continued to remain a total mystery to the Luftwaffe.[19]

When World War II commenced with the Nazi invasion of Poland in September 1939, the British C&R system (the most sophisticated in the world) was functioning smoothly. However, it would be the Battle of Britain that would put the system to the ultimate test.

The Battle of Britain

Flushed with confidence from the conquests of Austria, Czechoslovakia, Poland, Denmark, Norway, Holland, Belgium, Luxembourg, and finally France, Hitler's war machine now turned its attention to Great Britain. The fate of the British Isles, if not World War II itself, now hung in the balance. In preparing for the invasion of Britain (codenamed Operation Sea Lion), Hitler first charged his commander-in-chief of the Luftwaffe, Reichsmarschall Hermann Goering, to establish air superiority over England and the English Channel.[20] Said Goering in June 1940, "My Luftwaffe is invincible. So now we turn to England. How long will this one last—two, three weeks?"[21]

In June 1940, Prime Minister Winston Churchill expressed his grave forebodings of the impending battle:

> The Battle of France is over. I expect that the Battle of Britain is about to begin. Upon this battle depends the future of Christian civilization. Upon it depends our own British life, and the long continuity of our institutions and our Empire. The whole fury and might of the enemy must very soon be turned on us. Hitler knows that he will have to break us in this island or lose the war. If we can stand up to him, all Europe may be free and the life of the world may move forward into broad, sunlit uplands. But if we fail, then the whole world, including the United States, including all that we have known and cared for, will sink into the abyss of a new Dark Age made more sinister, and perhaps more protracted, by the lights of perverted science. Let us therefore brace ourselves

to our duties, and so bear ourselves that, if the British Empire and its Commonwealth last for a thousand years, men will still say, "This was their finest hour."[22]

Numbering only 2,300 pilots, the RAF was to protect England with approximately 600 Hawker Hurricane and Supermarine Spitfire fighters against nearly 1,000 Messerschmitt Bf 109 fighters protecting more than 1,400 Junkers Ju-88, Dornier Do 17, and Heinkel He 111 bombers. Never before in the history of warfare had so few men held the fate of a nation in their hands. Moreover, never before was such a crucial battle to be fought entirely in the air (figs. 3-9, 3-10, and 3-11). Officially lasting from 10 July to 31 October 1940, the Battle of Britain can be described as having been fought in four phases.[23]

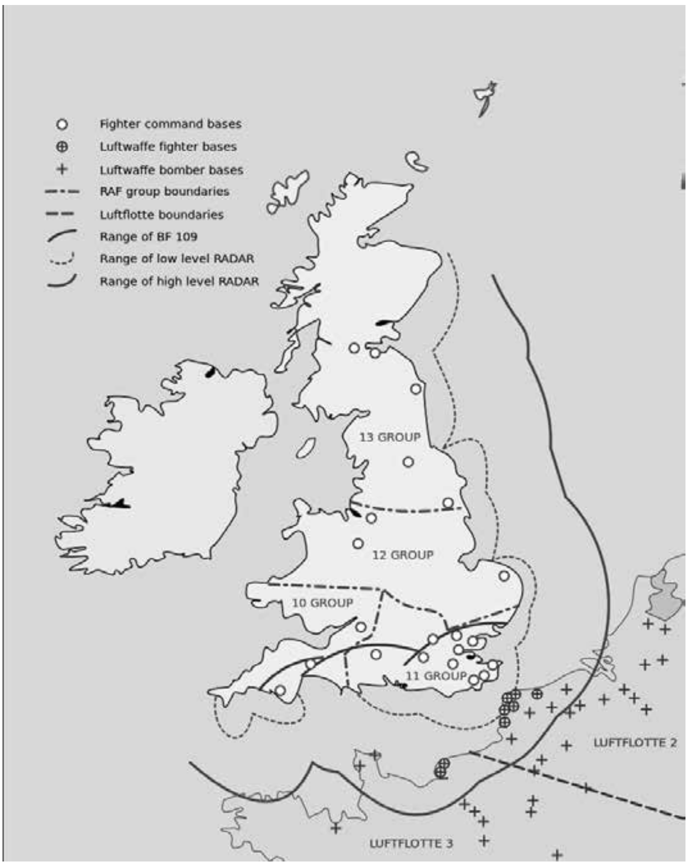

Figure 3-9. **Battle of Britain bases**. (Reproduced from Williamson Murray, *Strategy for Defeat: The Luftwaffe, 1933–1945* [Maxwell AFB, AL: Air University Press, 1983], 49.)

Figure 3-10. **"Come to readiness!"** (Reproduced from https://commons.wikimedia.org/wiki/File:Pilot_seen_running_to_fighter.jpg, IWM photo.)

Figure 3-11. **Supermarine Spitfire formation**. (Reproduced from https://commons.wikimedia.org/wiki/File:Supermarine_Spitfire_F_Mk_XIIs_of_41_Sqn.jpg.)

Phase One—Channel Warfare

Starting in July, the Battle began with German aerial attacks on British ships in the English Channel. RAF fighters, drawn in to protect the ships, were then shot down by the battle-tested Germans. In the first 10 days, 50 RAF fighters were destroyed by the superior Messerschmitts.[24] The British sector controllers soon realized that if they answered the German attacks plane for plane, they would be bled dry. At this rate, the Fighter Command would cease to exist in just six weeks.[25]

Determined to sink every ship passing through the channel, the Germans continued to launch dive-bombers, day after day. Typical of one day's efforts, a shipping convoy would fall under attack by more than 30 Junkers, protected by 50 Messerschmitts. However, the sector controller would launch only eight Spitfires into the air to engage the enemy to drive away the bombers. By the end of the day, of the original 20 ships in convoy, only four made it into port. RAF Air Marshal Dowding was pushed by the Admiralty to support the convoys with more fighters, but he refused. By August the British government decided it was easier to ship resources from western ports, then inland by rail, and so canceled all further Channel ship traffic. The restraint Dowding showed as he committed only a small handful of aircraft to engagements, and the reports brought back by Luftwaffe aircrews from their fighter engagements, encouraged the German high command to believe the RAF had few resources left. As he had originally bragged, Goering felt it would soon be over.[26]

Phase Two—Eagle Day

In August 1940 the Luftwaffe's huge fleet of Heinkel bombers, escorted by Messerschmitt fighters, began attacking in full force against RAF fighter bases and several RDF stations near the coast to pulverize the British into surrender. Day after day, RAF Fighter Command responded with as many as 600 sorties against the attackers. However, being outnumbered four-to-one, the RAF fighters were being routinely shot down or forced away. Now the Battle of Britain entered its most intensive phase. Goering had named 13 August as *Adlertag* or Eagle Day—the day on which the Luftwaffe's massive air offensive would finally wipe out the RAF.[27]

However, the sector controllers were now learning the tricks employed by the Luftwaffe. When a fighter sweep of Messerschmitts tried to draw the Spitfires away from their defensive positions, the controllers maintained their protective fighters patrolling closely over their airfields to engage any approaching bombers. By the end of Eagle Day, the Germans had mounted their greatest effort to date—launching 1,485 sorties and losing 46 aircraft. The RAF had responded with 700 sorties but lost 13 fighters and 47 more destroyed on the ground.[28] Both air forces were now locked in mortal combat.

Angered that his Eagle Day had not been triumphant, two days later, on 15 August, Goering launched his most intensive air assault during the Battle of Britain. Launching over 1,700 sorties (1,200 were fighter sorties) from bases in France all the way up to Norway, the Luftwaffe pounded targets and airfields all along England's eastern coast.[29] The RDF operators at the northern part of Chain Home, swamped with radar returns and lacking the experience of their southern colleagues, estimated the incoming raid size at about 30 aircraft. The sector controller scrambled his squadron. When the few fighters made visual contact, they found that the raid size was well over 100 "bandits"! Correctly concluding that this was the entire Luftwaffe's effort in the north, the 13 Group controller vectored squadrons from every airfield in the group. The German bombers were decimated, and the Messerschmitts were caught off guard by the bold response.[30]

As an estimated 150 German bandits approached the English shore, the sector controller changed his orders. The German fighters were being plotted at 25,000 feet, and so Spitfires, far better suited to engage the Messerschmitts at high altitude than the slower climbing Hurricanes, were being scrambled. RAF command-and-control tactics allowed Fighter Command to preserve its fighter assets and ensured the entire fighter force was not on the ground refueling and rearming at the same time. A tremendous air battle ranged from Scotland to Devon, eventually resulting in the RAF losing 34 fighters in aerial combat—but the Luftwaffe's losses totaled more than 75 aircraft. The Luftwaffe soon began to refer to 15 August as "Black Thursday."[31] Churchill famously said, after these two months of fighting:

> The gratitude of every home in our island, in our Empire, and indeed throughout the world, except in the abodes of the guilty, goes out to the British airmen who, undaunted by odds, unwearied in their constant challenge and mortal danger, are turning the tide of the World War by their prowess and by their devotion. Never in the field of human conflict was so much owed by so many to so few.[32]

Phase Three—The "Crucial Period"

The Germans were now changing their tactics and abandoned airfield and RDF station attacks and, on direct orders of Goering himself, switched to bombing aircraft production factories. Had the Luftwaffe continued to attack RAF airfields exclusively, the RAF might well have been grounded, and the Germans could have gained command of the air over southeastern England. No longer under direct attack, the RAF Groups gained critical time needed to repair their damaged airfields and RDF towers and to rest their exhausted pilots and ground crews. Nevertheless, the RAF had lost 25 percent of its pilots, who were replaced by flyers just arrived from training with less than two weeks' squadron flying experience. Dowding wondered how he could keep English skies dangerous enough to delay a German invasion until wintertime with its tempestuous seas. At this rate, however, it seemed impossible.[33]

Phase Four—London Bombing

On 25 August a lone German bomber aircrew changed the course of the war. Slated to attack oil tanks at Thameshaven, the aircrew lost its way and dropped their bombs—in error—hitting London. Furious, Churchill immediately authorized a reprisal raid. That same night, 81 RAF bombers struck Berlin. Outraged, Hitler demanded massive retribution and began the German terror raids on central London.[34] The controller of the southeastern group realized the Luftwaffe was now centering its attacks on London itself and scrambled greater numbers of fighters to confront them en route to London.[35]

The deadly Messerschmitt escorts could not reach London, and the Luftwaffe bombers were now attacked by swarms of RAF fighters. As a result, bomber formations were repeatedly broken up or deflected and thus forced to turn back for home. The great air battle of 15 September 1940 is now celebrated as "Battle of Britain Day." The Germans sent 400 fighters to escort about 100 bombers part of the way to London, and Fighter Command ordered everything into the air. Nearly 200 Spitfires and Hurricanes swarmed high above London, attacking the now unescorted bombers, and nearly 300 RAF fighter sorties were launched that day against German fighter escorts (fig. 3-12).

This massive concentration of fighters, larger than anything ever previously displayed by the RAF, convinced the Luftwaffe that Fighter Command was far from being the beaten force that German intelligence was portraying. The sight of such a large fighter force—miraculously intercepting the Luftwaffe everywhere it turned—shattered German hopes.[36]

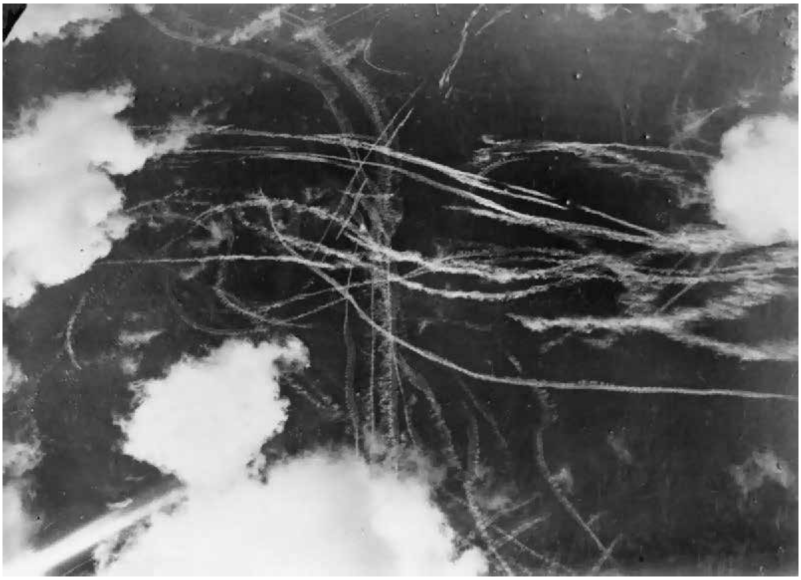

Figure 3-12. **British and German dogfight vapor trails**. (Reproduced from https://commons.wikimedia.org/wiki/File:British_and_German_aircraft_a_dog_fight.jpg, IWM photo.)

Two days later, British intelligence intercepted a secret German radio message instruction for the dismantling of German airfields in Holland—Operation Sea Lion's invasion of England was being postponed! For the Luftwaffe, it was just as well. Exhausted by the summer battles, the bomber units were depleted, and morale was low. Week after week, the RAF held its own against tremendous odds. Meanwhile, the Luftwaffe had become baffled, then frustrated, and finally completely disillusioned. How had RAF fighters known where and when to strike their bombers? Goering now turned his attentions to the techniques of nighttime bombing, and Hitler turned to maps of Russia.[37]

Just by fighting to remain intact, Fighter Command had won the Battle of Britain. It had won it thanks to the bravery of the RAF pilots, to the Spitfire and Hurricane fighters and those who maintained them, to Dowding's unswerving leadership, and—most definitely—to the sector controllers and their secret RDF. The Germans believed British fighters were somehow being controlled by local radio stations, and not by a vast, nationwide radar and radio command-and-control network. Luftwaffe signal interception units heard the process of RAF fighter squadrons being talked into battle. It was becoming evident, although not known how, that British officers somewhere near London somehow knew when German aircraft were airborne and from what direction they were attacking.[38] Then there was the incomprehensible English phrase repeatedly being shouted by RAF flight leaders back to their controllers—"Tally Ho! Tally Ho!"[39]

Overall, Chain Home and the C&R system had allowed the outnumbered British fighters to turn up at the right time, even while outnumbered, to intercept Luftwaffe raids time after time after time. Said Gen Adolf Galland, one of the great German fighter aces of the war, who would eventually command the fighter defenses of the Third Reich, "From the very beginning the British had an extraordinary advantage which we could never overcome throughout the war—radar and fighter control. For us and for our command this was a surprise, and a very bitter one. The British fighter was guided all the way from takeoff to his correct position for an attack on the German formations. We had nothing of the kind."[40]

The Introduction of Ground-Controlled Interception

With their success in radar development, British radar engineers in August 1940 replaced several of the huge 350-foot fixed antennas of the Chain Home network with a new, smaller, rotating antenna that was used for transmitting and receiving radar pulses—a technological marvel. They also unveiled a new type of radar scope to replace the A-scope, called a plan position indicator (PPI). The term "plan position" described the scope's view as being planar, or a "bird's eye view" from above, rather than the standard side-view presentation then in use by radar operators.

The PPI was a round cathode ray tube that had a rotating beam of light called a "sweep," turning like a clock's second hand around the center of the tube in exact synchronization with the turning of the radar antenna as it transmitted. Radar echoes collected by the same turned antenna appeared as points of light called "blips" along the sweep as it rotated. A coating on the scope provided a phosphorescent afterglow so that a target's reflection remained visible until renewed by the next sweep. What we now traditionally picture as being the typical radar screen, it was, in fact, an astounding breakthrough. Moreover, it paved the way for a new form of more closely controlling aircraft—ground-controlled interception (GCI) (fig. 3-13).[41]

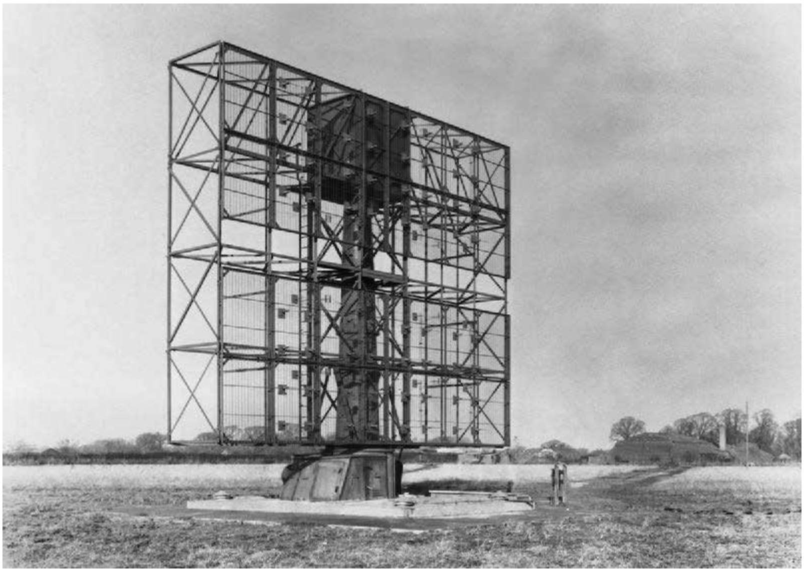

Figure 3-13. Rotating GCI radar. (Reproduced from https://en.wikipedia.org/wiki/Dowding_system#/media/File:GCI_(Ground_Control_of_Interception)_radar_installation_at_RAF_Sopley,_Hampshire,_1945._CH 15188.jpg, IWM photo.)

Obviously, for controlling fighters to intercept enemy aircraft, particularly during night interceptions, GCI with its marvelous PPI far surpassed the cumbersome filtering of returns and the time-consuming plotting on situation maps. For the first time, a GCI controller could actually "see" the aircraft as they flew across the countryside, rather than watching voiced plots being pushed across a map. By studying the PPI, the GCI controller could determine the positions of the fighters, identified by the newly invented identification-friend-or-foe (IFF) technology, the RAF's Mark I IFF system, and those of the enemy, not displaying a friendly IFF signal. The GCI controller could then provide timely R/T code word instructions directly to the fighter to successfully conduct the interception. The ingenious GCI transformed the British radar system from one providing a basic early warning capability into an actual means for dependable air interception control.

Clearly, the invention of GCI was as significant as the invention of pulse radar detection itself (fig. 3-14).

Figure 3-14. **GCI controller and plotters**. (Reproduced from http://www.raf.mod.uk/news/archive.cfm?storyid=E46A70BC-5056-A318-A867D-971EE41E2CA, RAF photo.)

The first GCI sets were built at the Telecommunications Research Establishment at Worth Matravers, on England's southern coast in spring 1940, too late for use during the Battle of Britain, and began its series of operational tests. Wrote one research engineer:

> During that lovely summer, we often saw hostile day bombers passing over us. One day we counted seventy-two of them . . . . After our day's work, many of us went to our GCI station, hoping that this would be the night on which civilian scientists working as controllers at a research station would be the means of bringing down a night bomber . . . it is sad to record that [they] . . . failed to obtain a kill. They were replaced by RAF controllers who, in fact, did the job much better.[42]

The first RAF GCI sets were called Chain Home–Low (CHL), as they provided low-altitude air coverage along the British coastline. The first operational CHL/GCI set went on watch on 18 October 1940. Six sets replaced RDF stations by Christmas, and a total of 12 were on duty by January 1941.[43] These first CHL/GCI stations were either fixed or transportable, requiring eight vehicles, operated at about 209 MHz, had a peak power of around 100 kW, and had a detection range of over 90 miles.[44]

GCI was proving itself to be especially critical in assisting RAF fighters to attack German nighttime bombing raids on London, which were now becoming the norm, as radar was the only certain means to detect and intercept bombers in the dark. Serious night bombing of London had begun in September 1940, and until mid-November, except for one night of bad weather, an average of 160 German bombers attacked the city every 24 hours. This was the "Blitz."[45]

Throughout the Battle of Britain, visiting American Army Signal Corps and Air Corps officers watched the RAF's radar air defense system with keen interest, especially the new and fantastic GCI. As they watched over the shoulders of their soon-to-be wartime allies, these officers were busily taking notes and analyzing what steps would be needed to help the US Army's Aircraft Warning Service begin to take shape. For unlike the RAF, by 1940 the Army had only a few research radar sets, no GCI, no radar network, and no controllers. There was much to be done.

Notes

1. Watson–Watt, *Pulse of Radar*, 114.
2. Wood and Dempster. *Narrow Margin*, 79.
3. Ibid.
4. Ibid.
5. Millar, *Bruneval Raid*, 27.
6. Watson–Watt, *Pulse of Radar*, 115.
7. Bickers, *Battle of Britain*, 30.
8. Gough, *Watching the Skies: The History of Ground Radar in the Air Defense of the United Kingdom*, (Her Majesty's Stationery Office, 1993), 6.
9. Ibid., 4.
10. Bickers, *Battle of Britain*, 31.
11. Deighton, *Fighter*, 114.
12. Ramsay, *Battle of Britain Then and Now,* 14–28.
13. Bickers, *Battle of Britain*, 35.
14. Ibid, 33–4.
15. Bungay, *Most Dangerous Enemy*, 49.
16. Swords, *Technical History*, 195.
17. Brown, *Radar History of World War II*, 97–8.
18. Ibid.
19. Millar, *Bruneval Raid*, 36–7.
20. Deighton, *Fighter*, 31.

21. Moll, "Battle of Britain," 45.
22. Ibid, 42.
23. Deighton, *Fighter*, 140.
24. Moll, "Battle of Britain," 47.
25. Deighton, *Fighter*, 164.
26. Ibid., 176, 179.
27. Ibid., 173, 196.
28. Ibid., 199–200.
29. Ibid, 207.
30. Ibid, 205.
31. Ibid, 211.
32. Moll, "Battle of Britain," 52.
33. Deighton, *Fighter*, 250–2.
34. Ibid. 252.
35. Ibid. 226–7.
36. Ibid. 262.
37. Ibid., 262–3.
38. Ibid. 187.
39. Millar, *Bruneval Raid*, 45–6.
40. Moll, "Battle of Britain," 45, 50.
41. Putley, "Ground Control Interception," 162–3.
42. Millar, *Bruneval Raid*, 93.
43. Swords, *Technical History*, 239.
44. Watson–Watt, *Pulse of Radar*, 218.
45. Millar, *Bruneval Raid*, 68.

Chapter 4

The American Aircraft Warning Service Takes Shape

The Army Air Defense Command

As previously mentioned, in 1933 the US Army had undertaken a major reorganization to better carry out its territorial defense responsibilities. Four major continental defense field armies (First United States Army, Second United States Army, Third United States Army, and Fourth United States Army) were established with specific geographical areas of responsibility. Within each of these four field armies there also existed an air district responsible for controlling the field army's limited air assets operated by Air Corps personnel.[1] Later, in 1935, the War Department issued its general directive on air defense to the four field army commanders designed to prepare an integrated air defense consisting of field-army-controlled pursuit aviation, AAA, and aircraft warning services for defending against coastal air attacks.[2]

During summer 1939, with the Signal Corps's breakthroughs in developing the SCR-268 short-range and SCR-270 long-range radars, the Army announced that new secret electronic "detectors" would soon replace sound locater equipment for air defense. Further, the Signal Corps was ordered to begin researching possible detector sites and information center locations that would be required in the future.[3] The future arrived that fall. In September 1939, Germany invaded Poland, and Europe was plunged into war. Shocked by this act of aggression, the United States was now confronted with having to seriously reconsider its self-defense needs.

Gen Hap Arnold, now chief of the Air Corps (fig. 4-1), was particularly worried about the lack of an organized continental air defense and urged that a study be conducted to review this problem. The study, completed in early 1940, recommended that 23 long-range detector sites be positioned around the United States, providing air defense information to nine centralized information centers.[4] Without an air defense system to protect its thousands of miles of coastline, the Army had a very long way to go.

Figure 4-1. **Gen Hap Arnold**. (Reproduced from https://upload.wikimedia.org/wikipedia/commons/3/37/021002-O-9999G-013.jpg, US Army photo.)

The security of the strategic Panama Canal was of immediate concern to the War Department. On 1 January 1940, the Signal Company, Aircraft Warning, Panama, was established and ordered to prepare for deployment to the Canal Zone (CZ). Consisting of 93 men pulled from numerous Signal Corps units, this first-of-its-kind company went into emergency training at Fort Monmouth. Using the SCL's fixed SCR-271 research radar set, they practiced "the strange and uncertain business of electronic detection." It was uncertain that they would have their own radar set by the time they arrived in Panama later that year.[5]

Having just witnessed the successful SCR-270 tests at Fort Hancock, CZ, in December 1939 and with the results of General Arnold's air defense study, Secretary of War Woodring announced that a new command would soon be established in the Northeastern United States to provide warning and air defense against attacks. Two months later, in February 1940, the War Department officially announced the establishment of the experimental Air Defense Command (ADC) at Mitchel Field, on Long Island, New York, under the command of Air

Corps Brig Gen James Chaney (fig. 4-2).[6] The ADC, operating in the northeast United States under the direction of the First Army commander, was to serve as a model for a nationwide air defense command system. This air reorganization was only partially carried through in 1940; the air districts were not activated until 15 January 1941, and the expansion of the air defense command system was not approved until March1941. Staffed with only 10 officers, ADC would be responsible for coordinating the three components of air defense—AAA guns and searchlights, Air Corps pursuit planes, and Signal Corps detection and communication equipment—into a functional AWS structure to support First Army.[7]

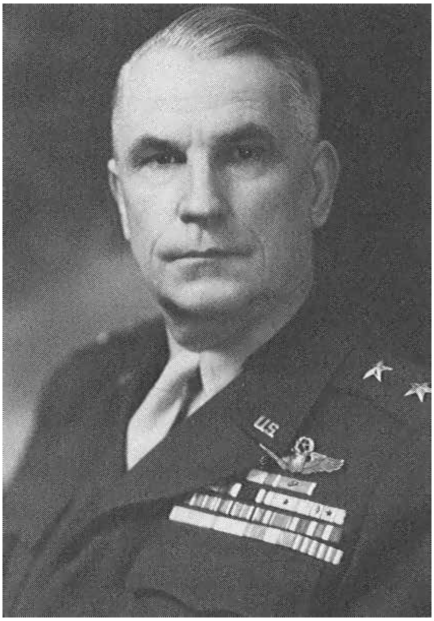

Figure 4-2. **Maj Gen James Chaney**. (Reprinted from Kenneth Schaffel, *The Emerging Shield: The Air Force and the Evolution of Continental Air Defense, 1945–1960* [Washington, DC: Office of Air Force History, 1991], 25, http://media.defense.gov/2010/May/26/2001330263/-1/-1/0/AFD-100526-024.pdf.)

ADC was viewed as primarily a planning organization, charged with developing a system of unified air defenses for cities, vital industrial areas, and continental bases within First Army's area of responsibility.

It would also cooperate closely with the British RAF during its upcoming Battle of Britain, observing radar and fighter control employment in actual combat.[8] ADC asked the War Department in February 1940 for permission to recruit an initial cadre for AWS duty and promised they would be trained and ready for the July 1940 maneuvers, quite a promise since there were still very few SCR-268 radars in service. They had just started to arrive from SCL during the past year. Only one SCR-270 existed (still at Fort Hancock completing final Army service testing), plus one fixed SCR-271, the SCL's research set still undergoing development and being shared with the recently formed Panama AWS troops for their hasty training.[9]

Amazingly, the War Department granted the recruiting request, and on 1 March 1940, the 1st Signal Aircraft Warning Company (SAWC) was activated. It would be the first of over a hundred Army SAWCs that would be formed during World War II. The company's initial troop strength consisted of 30 signalmen from Fort Monmouth, 10 men from other units, and 43 new recruits—all of whom would soon report to Fort Monmouth to begin necessary training on the soon-to-be certified SCR-270 set.[10] The building of AW units was now officially underway. During spring 1940, as Hitler's blitzkrieg stormed across Europe, the War Department ordered the First Army to establish a formal AWS network along the eastern seaboard. The Third Army was to develop an AWS from the Carolinas to the Gulf of Mexico; and the Fourth Army, cooperating with Second Army, was to establish its AWS along the entire Pacific coastline.[11]

Army officers visiting England were also to observe the British air defense system, and they were now returning with enthusiastic reports about the RAF's successful radar network. Consequently, in May 1940 the War Department ordered the commanders of the four field armies to immediately begin incorporating the newly developed radar sets, codenamed "radio-B" detectors, into their AWS networks.[12] To support this monumental tasking, the ADC and the Signal Corps now began drafting the first plans to provide for the air defense of the United States. They planned on using 31 mobile detectors ringing the four continental air districts, which would require a staggering total of 3,786 AW signal troops.[13]

In August 1940, ADC was ordered to participate in First Army maneuvers in New York, one of the purposes being "to develop a system of unified air defense for the protection of armies in the field."[14] Again, the telephone company was pressed into service, connecting

360 observation posts and 46 fire lookout stations to an information center at Watertown, New York (fig. 4-3). Using over 4,600 civilian observers, it was the largest exercise of an AWS held to that date. The final report stated, "Methods employed in the organization and operation of the Aircraft Warning Service, with revisions indicated by present experience in the maneuvers, are considered very satisfactory as a guide to future operations."[15]

Figure 4-3. **Air defense exercise at Watertown, New York, 1940**. (Reproduced from Schaffel, *The Emerging Shield*, 28.)

Participating in the First Army maneuvers gave ADC its first valuable experience in preparing and testing air defense methods. Now it could begin preparing detailed plans for various coastal sectors, using personnel and facilities of the US Forest Service, railroads, electric utility companies, and other organizations. By December 1940, rudimentary air defense information centers had been built in several major cities on both the Atlantic and Pacific coasts. Word was now circulating, however, that the War Department was planning to transfer the entire air defense mission to the Air Corps.[16]

In January 1941, ADC undertook a huge "Test Sector" exercise involving most of Massachusetts, Connecticut, Rhode Island, and Long Island, New York. Boundaries were specifically chosen to test coordination problems between the Boston and New York information centers (fig. 4-4). Each information and filter center was organized differently to test the relative efficiencies of skilled women telephone operators, untrained civilian volunteers, and skilled military personnel. Some 700 observation posts were manned by more than 10,000 civilian observers. No doubt influenced by the RAF's successful system, filtered information was transmitted to plotters where it was displayed for the benefit of the controllers in making their tactical decisions.

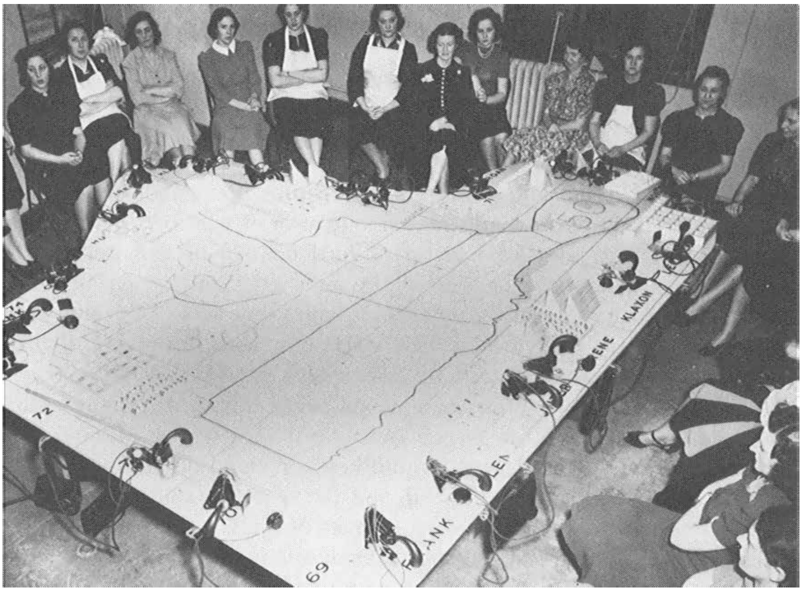

Figure 4-4. **Air defense exercise at New York City, 1941**. (Reproduced from Schaffel, *The Emerging Shield,* 31.)

ADC was disappointed with the performance of the ground observers. They had used only instruments provided by mail, and the quality of observations varied widely. The experimental use of women in the centers had gone well, however. Overall, ADC recommended that critical AWS military personnel should only be required as instructors or supervisors and concluded that civilians could perform most of the duties carried out at each center.

In March 1941 the rumor that air defense would be transferred to the Air Corps became fact, and by June ADC ceased to exist. In the single year of its existence, however, ADC had generated a revolution in air defense thought. Pursuit aircraft were now viewed as the principle defense against aerial attack, and an effective AWS was seen as the key to successful interception. As ADC expressed it:

> The Aircraft Warning Service does not merely “alert” defending pursuit aviation; it furnishes pursuit with the detailed, timely, and continuous intelligence necessary for pursuit interception. A proper conception of an Aircraft Warning Service is that of a complex and highly organized service carefully adjusting to the tactical requirements of the agencies it serves and efficiently integrating into the defense of a strategic area.[17]

Overseas Air Defense Planning

The fall of France to the German war machine in June 1940 meant time was now of the essence. Congress was now considering a national mobilization, which would result in expanding the US Army to 375,000 personnel. As a result, a Signal Corps board was held in Washington, DC, that month to determine how many AW troops it would require as part of this build-up. Out of this board came a plan that the National Guard would be especially suitable for aircraft warning duty and they could study the SCR-270 in their local armories. The board urged that SAWCs be organized in every coastal state where detector stations were being planned. It was envisaged that Guardsmen could join in the air defense of their section of the country, defending their hometowns in much the same tradition of Lexington and Concord.[18]

However, despite the modest successes achieved by the ADC, it was clearly apparent that the Army was unprepared to conduct any major continental air defense operations and was now under enormous pressure to develop serious air defense plans for the nation. Overseas, it was the same story. At the beginning of 1940, the Army chief of staff, Gen George C. Marshall, cautioned: “As long as the British Fleet remains undefeated and England holds out, the Western Hemisphere is in little danger of direct attack.” However, he added, “the situation would become radically changed” if the British Fleet were to be sunk or to surrender.[19] Therefore, plans had to be drawn up immediately to meet this possibility as well.

Defending American interests in the Western Hemisphere were the Army’s small overseas garrisons, which were organized into four major departments: the Panama Canal and Puerto Rico departments in the Caribbean, the Hawaiian Department in the Pacific, and the Philippines Department in the Far East.[20] With the war now consuming Europe, the Signal Corps worried whether its various overseas

AWS efforts in each of these departments would be enough, or even in time.

Having completed their brief training at Fort Monmouth, the unique Signal Company, Aircraft Warning, Panama, left for the CZ in May 1940. Their mission had such high priority they wound up taking the SCL's research SCR-271 with them. They were to guard the Canal's Caribbean approaches from Fort Sherman and the second station on Taboga Island on the Pacific side. The Fort Sherman site became the Army's first operational radar station (fig. 4-5).[21]

Figure 4-5. **SCR-271 radar station in Panama**. (Reproduced from Dulany Terrett, *US Army in World War II: The Technical Services: The Signal Corps: The Emergency* [Washington, DC: Office of the Chief of Military History, 1956], 285.)

In August 1940, Winston Churchill offered British territories for US defense garrisons, in trade for old US Navy destroyers, which the Royal Navy desperately needed. Consequently, plans were soon drafted by the Air Corps for deploying small air defense fighter forces to the islands of Bermuda, the Bahamas, Jamaica, and Trinidad to protect strategic air and sea lanes in the Caribbean. Included in these plans were AWS frontier companies at each location.[22] To protect the Atlantic sea lines of communication between the United States and Europe, planning now began to move air defense aircraft and AW units to Newfoundland (Canada), Greenland, and Iceland to check possible German North Atlantic troop movements or ship assaults.[23] Plans were started during 1940 to activate and deploy AW units and pursuit aircraft to Alaska, while additional AW units were to augment the existing pursuit squadrons currently in the Philippines and Hawaii. Unfortunately, while plans were being made to send troops and materiel to these locations, no radar sets were yet available to deploy with them—nor would there be for yet another 18 months, until fall 1941.[24]

The need for AW companies became relentless, and it was quickly apparent that the planned requirement for new AW units would soon exceed the available number of currently trained AW personnel. In May 1941, a newly formed Air Defense board, consisting of senior ranking Air Corps, Signal Corps, and Coast Artillery Corps (CAC) officers, held its first meeting in Washington, DC, to survey the Army's AW planning and to propose possible solutions. The board determined the Air Corps should be strengthened by 1,238 officers and 7,796 enlisted men to implement its share of the air defense system.[25] In September 1941, the Air Defense Board recommended the Signal Corps increase its AW personnel by an additional 2,200 officers and 40,200 enlisted men. For the Signal Corps alone, this tripled the number of men currently on AW duty at the time. Of this new recommended total, the War Department approved 900 officers and 17,000 enlisted men to begin training by that December.[26]

This increase still did not prove enough. Another board, held by the War Department in November 1941, concluded the "organization, activation, training and equipment of AWS units had not kept pace with the expansion of pursuit units." While there were 13 aircraft pursuit groups at the time, only five AW companies had officially been formed—no AW battalions existed, let alone AW regiments. The board stated, "the present situation places the provision of pursuit Aircraft Warning Service teams at the earliest date in priority, far above the foreseeable demands for any units in the United States Army."[27]

The effort to build a pool of trained personnel for AWS duty since fall 1940 had produced approximately 2,900 trained AW enlisted men. However, now, with plans being drawn up to quickly deploy AW units overseas to task forces in Panama, the Caribbean, the North Atlantic, Alaska, Hawaii, and the Philippines, the board recommended a second AWS recruiting effort of an additional 986 officers and 17,106 enlisted men to begin in December 1941.[28]

Signal Corps Aircraft Warning Training

Technical training was a major mission of the Signal Corps—and now the urgency of national mobilization demanded that it cut that technical training time drastically (fig. 4-6). While the Fort Monmouth's Signal Corps School normally required 10 full months for training enlisted troops, the Army had too few officers to allow them to attend such lengthy special schooling during the growing crisis. Therefore, National Guard and Reserve Signal Corps officer training was reduced at the school from nine months to only three months. Graduates were soon ridiculed as "ninety-day wonders." Assuming West Point graduates were capable of even quicker study, the regular officer's course was cut to just a single month overview of wire, radio, photography, and the newly emerging aircraft warning service. All enlisted technical training was shortened to just three months or less. There was no other way—the growing emergency demanded it.[29]

Figure 4-6. **Signal Corps field training class**. (Reproduced from Terrett, *The Emergency*, 75.)

Later in summer 1940, the United States began its long road to national rearmament. While the Battle of Britain was being fiercely waged in Europe, all four US Army field armies began massive efforts to improve their readiness, including practicing air defense methods in earnest for the first time. The Third Army conducted its largest peacetime ground maneuvers to that date in Louisiana, but it had to improvise its AWS company. Meanwhile, during field maneuvers in the Northwest, the Second Army complained to the War Department that it had no aircraft or AWS at all with which to train. Overall, training went agonizingly slow due to the lack of both materiel and workforce. With great frustration, one general reported that he hoped "to have a defense force in the next two or three years."[30]

That fall, unable to resist the fears of being unprepared any longer, Congress passed the Selective Service Act of 1940, authorizing conscription and an Army of 1.4 million personnel—a ten-fold increase in size. The United States was now officially mobilizing for war. By October 1940, the draft was in full swing, and new inductees began pouring by the thousands into Army and Navy induction centers across the country.[31] The Signal Corps responded to this challenge by establishing, over the course of 18 months, three major electronic training centers related to radar or AWS operations:

- The Eastern Signal Corps Training Center (at Fort Monmouth, New Jersey) was home of the existing Signal Corps School, as well as the Signal Corps's own Officer Candidate School, and was responsible for most Army radio and telephone training throughout the war.

- Later, in February 1942, the Midwestern Signal Corps Training Center (at Camp Crowder, near Neosho, Missouri) would become the Signal Corps's largest replacement training center. It would offer many of the basic signalman training courses, as well as specific AWS classes.[32]

- Finally, in June 1942, the Southern Signal Corps School, located at Camp Murphy, on Hobe Sound near Riviera, Florida, would begin teaching trainees how to repair the new and intricate SCR-268 and SCR-270 series radar sets.[33]

For every newly arriving recruit, the first days at Camp Crowder were spent in a succession of queues for filling out forms, assembling a uniform, getting a haircut, shots, and more forms. These first three weeks of basic training were spent learning how to march, wear a uniform, salute, do push-ups, pitch a tent, put on a gas mask, and fire a pistol.[34]

Only after successfully learning how to be a soldier did these recruits begin their AW technical training. For many, it was on to Fort Monmouth's Signal Corps School, the Army's primary electronics training school, for advanced signalman training. Fort Monmouth was soon flooded with trainees arriving at a rate of 7,000 students per quarter. By January 1941, the commandant of the school was forced to lease 10 extra acres to pitch winterized tents to hold the overflowing population. In time, the school would conduct basic signalman classes to over 5,000 trainees at once (figs. 4-7, 4-8, and 4-9).[35]

In March 1941, responding to concerns about the lack of specific AW technical training, the school began developing several new courses required for the still-experimental AW companies being planned. It recommended that radar maintenance training be conducted to no more than 100 students at a time, as no one knew very much about the still highly classified radio-B equipment (fig. 4-10). As a beginning cadre, five noncommissioned officers were chosen to become the department's first radar instructors. They were first put through a short course in radar maintenance, followed by a brief course in radar operations—that was enough for a start.[36]

Figure 4-7. **Arriving at Fort Monmouth for training**. (Reproduced from Terrett, *The Emergency*, 75.)

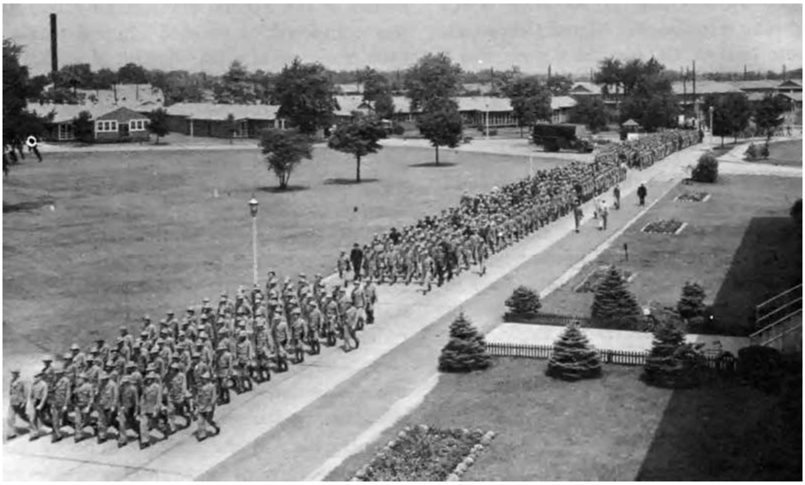

Figure 4-8. **Marching to class at Fort Monmouth**. (Reproduced from Thompson, Harris, Oakes, and Terrett, *The Test*, 202.)

Figure 4-9. **Fort Monmouth electronics training**. (Reproduced from Terrett, *The Emergency*, 213.)

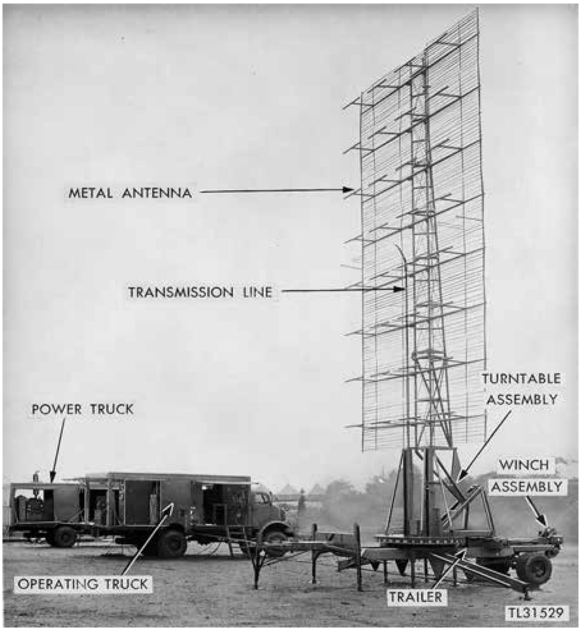

Figure 4-10. SCR-270 mobile radar. (Reproduced from photo by 1st Lt Harold Zahl, https://commons.wikimedia.org/wiki/File:SCR-270-set-up.jpg,)

Thus, in June 1941, the school's new Aircraft Warning Department officially opened at Fort Monmouth, with the first radar equipment class consisting of 10 officers and 40 enlisted men. Training lasted four months and borrowed from Fort Hancock the first mobile SCR-270 radar certified for Army use. Within a year, the capacity of the AW Department would swell to over 400 students.[37] The AW Department would soon institute a nine-week AW plotters course and a 13-week AW operations course, as well.[38]

However, the AWS radar maintenance requirement eventually grew so large it finally exceeded the AW Department's capacity. At the same time, a proposal to create a new, joint Signal Corps–Coast Artillery Corps–Air Corps training school had been under consideration. In October 1941, Secretary of War Stimpson approved this creative idea, and the Signal Corps's new Camp Murphy radar school was soon under construction.[39]

Located on 11,500 acres of inaccessible swampland near West Palm Beach, Florida, it was the perfect location to discourage unwanted observations of secret radar training. The new school devoted two months to the study of electronics principles and one month to radar, UF, and microwave principles. Graduates then went on to aircraft warning or antiaircraft units where radar played a predominant role or to Signal Corps depots to manage the acquisition, supply, and repair of the Army's newly arriving radar sets.[40] Classes began at Camp Murphy in June 1942. However, like the rest of the Army, the school immediately lacked enough radar sets for training, having only six SCR-268s for the Gun Laying Division and two SCR-270s for the Reporting Division courses.[41] Overall, radar students had to be highly motivated and have considerable initiative to learn and master the difficult topics of radar theory and equipment maintenance. As such, these radar repairmen were considered the elite—the "Phi Beta Kappa" of the Signal Corps.

Notes

1. Conn, Engelman, and Fairchild, *Guarding the United States*, 119.
2. Ibid., 54.
3. Terrett, *Emergency*, 136.
4. Conn, Engelman, and Fairchild, *Guarding the United States*, 62.
5. Terrett, *Emergency*, 149.
6. Ravenstein, *Organization and Lineage*, 12.
7. Conn, Engelman, and Fairchild, *Guarding the United States*, 24.
8. Williams and Fellow, "Deployment of Army Air Forces," 152–3.
9. Terrett, *Emergency*, 150–1.
10. Ibid.
11. Fourth Air Force. *Defense Plans and Operations*, 75–6.
12. Williams and Fellow, "Deployment of Army Air Forces," 153.
13. Terrett, *Emergency*, 151.
14. History, Air Defense Command, chapter 1 and 101–9.
15. Ibid., 259 and Appendix XI.
16. Fourth Air Force. *Defense Plans and Operations*, 75–6.
17. History, Air Defense Command, chapter 1 and 117.
18. Terrett, *Emergency*, 161.
19. Conn, Engelman, and Fairchild, *Guarding the United States*, 9.
20. Ibid., 392.
21. Terrett, *Emergency*, 151.
22. Conn, Engelman, and Fairchild, *Guarding the United States*, 364.
23. Ibid., 358.
24. Terrett, *Emergency*, 151.
25. Ibid., 287.
26. Thompson, Harris, Oakes, and Terrett, *Test*, 24.
27. History, III Fighter Command, vol. 2, 91–2.
28. Ibid., 93.

29. Terrett, *Emergency*, 210.
30. Ibid., 151.
31. Ibid., 203–4.
32. Thompson, Harris, Oakes, and Terrett, *Test*, 189–97.
33. Ibid., 212.
34. Terrett, *Emergency,* 215*;* and Thompson, Harris, Oakes, and Terrett, *Test,* 190.
35. Terrett, *Emergency*, 212–3.
36. Ibid., 218–9.
37. Ibid., 219.
38. Thompson, Harris, Oakes, and Terrett, *Test*, 53.
39. Ibid., 54.
40. Ibid., 288.
41. Ibid., 213.

Chapter 5

The Army Air Forces Take Charge

First Radars Arrive

In August 1940, Congressional funding totaling $1 million ($17 million in 2018 dollars) was secretly appropriated to fund a contract to build SCR-268s. It was an unheard of sum for a government investment in a single item, and industry was unprepared to deal with it. The Western Electric Corporation took up the challenge, protected from the risk by its cushion of existing laboratories and massive research capital.[1]

However, to most airmen, the American radar set was not worth the effort. As early as October 1940, a Signal Corps representative in London recommended the United States immediately purchase RAF radar, radio, and other equipment directly from the British government, saying that "beyond a doubt, the British detectors are much farther advanced than those we are developing in the United States." General Arnold recommended in November 1940 not only that copies of the RAF radar be reproduced but also that production of what he felt was the less-capable SCR-268 should be stopped.[2] Even though the RAF's Chain Home radar had less range and wasn't mobile, the Air Corps still viewed it as being more desirable. Moreover, the overall effectiveness of the RAF C&R network gave the false impression the American equipment was inadequate, rather than the inadequacy of the Army's untrained or inexperienced radar operators.

During summer 1940, the commander of the Air Defense Command, General Chaney, visited England to observe firsthand the RAF radar defenses that were proving themselves so successful during the Battle of Britain. Chaney's secret report to the War Department described the British AWS structure, the types of radar equipment they were using, and their aircraft controlling procedures. The report was later distributed to the four field armies air districts to study and use in AWS planning.[3] Having seen the fantastic capabilities of the new GCI radar, General Chaney demanded that US radars be made equally as capable as those of the British, that building US radar capabilities was among his highest priorities, and that the Army take "immediate action."[4] Air Corps observers were also dazzled by GCI and requested the SCR-268 be improved to a 70-mile range, a three-mile azimuth accuracy, and an elevation sensitivity within 1,000 feet (see fig. 5-1). In General Arnold's view, the Signal Corps was the supplier to the Air Corps, this was what the Air Corps urgently needed, and so it was up to the Signal Corps to get it—and get it fast! It was simple as that.[5]

Figure 5-1. **SCR-268 mobile radar**. (Reproduced from Terrett, *The Emergency*, 126.)

Pressured by the Air Corps, the Signal Corps began special efforts to increase the range of the SCR-268. These efforts resulted in the development of a new set designated "SCR-516" and gave the SCR-270 a new height-finding capability.[6] The Signal Corps was also able to obtain from the Army $2,646,000 ($47 million in 2018 dollars) to directly procure British equipment for testing.[7] However, the British government hesitated to immediately provide the requested equipment, frustrating the Signal Corps's research and development efforts, as well as fueling Air Corps criticism.[8] Try as they might, and under intense pressure, the Fort Monmouth radar engineers were never able to turn their SCR-268 and SCR-270 sets into what they were not—British GCI radars.

In February 1941 the tide slowly began to turn. Almost four years after its first secret demonstration back in 1937, the first factory-built SCR-268 radar sets began arriving from Western Electric factories. These sets were immediately sent to support the growing number of AWS units now deploying overseas. A total of 491 radar sets would be delivered by Western Electric during 1941.[9] Eventually, nearly 2,000 SCR-268 radars would be built and deployed until they were declared obsolete in January 1944.[10] However, frustrated that air defense was going "nowhere fast," and believing the new SCR-268s were going to Army antiaircraft units exclusively, General Arnold requested (and received) 20 new SCR-268s for Air Corps use instead of the promised SCR-270 long-range early warning radars.[11] The new Western Electric sets were also solving the Signal Corps School's growing training problems. By the middle of 1941, having received two new commercial SCR-268 sets plus two custom-built SCR-270 sets delivered directly from the Signal Corps Lab, the Aircraft Warning Department was now finally able to increase its radar maintenance training course from 100 to over 400 students at one time (fig. 5-2).[12]

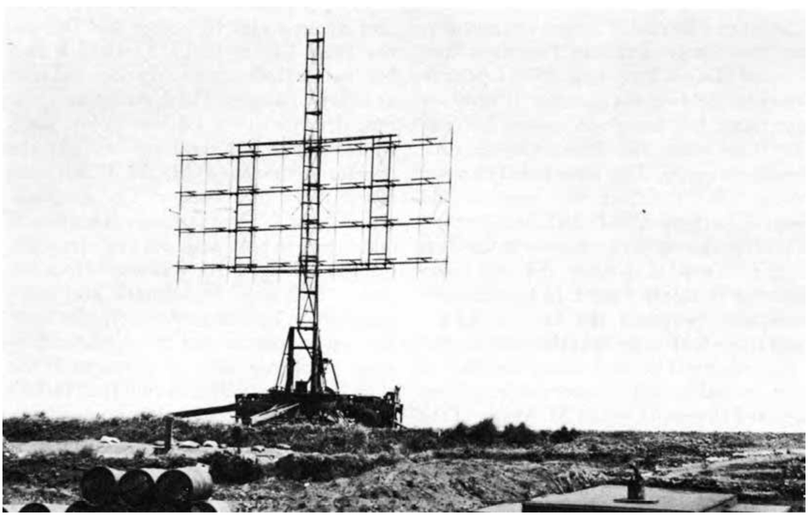

Figure 5-2. **SCR-270 mobile radar**. (Reproduced from Terrett, *The Emergency*, 126.)

Still not wanting to depend entirely on Signal Corps radar equipment, in May 1941 the War Department entered into a secret contract with the Canadian government (being part of the British Commonwealth) to produce 100 copies of the RAF's amazing GCI sets. President Roosevelt insisted that four sets be positioned in Panama, thus increasing the order to 104 sets. The Canadian-produced sets were given the Signal Corps designation "SCR-588" and were delivered without height-finding capability. Consequently, they could not be used for GCI, which was the reason for building them in the first place. The Canadians began research on an improved version to solve this problem. However, as late as June 1942, only 10 improved SCR-588B models would be delivered—testifying to the tremendous technical challenges of mass-producing GCI radar equipment.[13]

With frustrations building, the Signal Corps's answer to the Air Corps's desperate demands for detection equipment was that it took time to develop and build radar equipment and that all the Air Corps requests were on order. The Air Corps's response was that AW units were already deploying without needed equipment. The heat of the discussions became intense. This logistics problem became so severe that this massive Air Corps–Signal Corps argument eventually drew in the Chief of Staff and resulted in the immediate retirement of the Chief of the Signal Corps, Maj Gen Joseph Mauborgne, in August 1941.[14]

In late 1941, the British Ministry of Aircraft Production finally released much-sought-after British radio and radar equipment, resulting in a host of assorted VHF radios and IFF sets to examine—plus a genuine GCI set with the amazing PPI scope. Using this one set as a model, the General Electric Corporation eventually produced over 200 copies of the GCI radar, designated "SCR-527." However, they did not start arriving in units until spring 1943.[15]

With considerable caution, the Signal Corps could now finally say that progress was being made. Even General Arnold seemed temporarily satisfied, annotating one Signal Corps report with "this looks OK to me."[16] There still were not enough radar sets for every unit requiring them, nor were there enough qualified technicians to operate or maintain them. However, critical radar equipment was finally beginning to arrive.

New Air Defense Mission and Organization

From the beginning, the ADC was only envisioned as a planning staff, having authority to help organize, coordinate, and test new air defense concepts but without actual operational control over either aircraft or AAA. Those functions resided in the First Army itself. Moreover, since attack against the continental United States was unlikely except by air, General Chaney of the ADC argued that Air Corps officers should play a leading part in this defense effort.

In discussions within the Army, General Chaney proposed dividing the continental United States into four new regional defense commands, distinct from the four existing field armies that might deploy in wartime, thus leaving a region unprotected. Each defense command would have control over all regional elements of defense: ground troops, harbor defenses, pursuit aviation, AAA, and the aircraft warning service. If invaded, the defense command would become a theater of operations, and the defense commander would become the theater commander, with unified control over all military means within its theater.[17]

Agreeing with this concept, in March 1941, the War Department divided the United States into four defense commands—Northeastern, Southern, Central, and Western Defense Commands. The commanding general of each field army was also designated as the commanding general of the corresponding defense command to avoid parallel staffs.[18] This same order also directed that the continental air defense mission in its entirety should now belong to the Army Air Corps rather than the field armies.[19]

While the Signal Corps was still responsible for installing and operating AWS equipment, it was now the Air Corps that would control and employ it. This change would result in a constant source of friction between these two members of the AWS team and would eventually become a major theme. The ties between the two corps would be close but constantly strained.

This enormous transfer of responsibility added to the Air Corps's already tremendous growth, fueled by its urgent preparations for war, and created serious organizational problems for its chief of staff. Therefore, to better handle his new air defense responsibilities, General Arnold directed in March 1941 that the four former Army air districts become "numbered air forces," or NAFs, the first use of this new organizational designation. Each NAF was to act as an intermediate echelon between each of the 17 aircraft wings located across the United States and the Air Corps headquarters, providing a clearer organization of continental air defense efforts. These four were designated First Air Force (in the former Northeastern Air District), Second Air Force (in the former Northwestern Air District), Third Air Force (in the former Southern Air District), and Fourth Air Force (in the former Southwestern Air District) and were geographically collocated with the four existing continental field armies.[20]

In April 1941, the Air Corps further directed that each new NAF should divide its forces into two new subordinate commands, to be called "bomber commands" and "interceptor commands," to organize their offensive and defensive capabilities better. Each interceptor command was specifically responsible for the aircraft, AAA batteries, and searchlight units for that region. The following month, the Air Corps completed its air defense restructuring by directing each of the four NAFs to establish and operate their own regional aircraft warning service under the direct control of each interceptor command.[21] The interceptor commands were redesignated "fighter commands" in May 1942 when all pursuit groups and squadrons were also redesignated "fighter."[22]

Eventually, the four NAFs divided their areas of responsibilities into 18 different air defense sectors, each with its own information center:

- I Interceptor Command had its headquarters in Boston, and sector headquarters located in Philadelphia, New York City, Newark, New Jersey; and Norfolk, Virginia.
- II Interceptor Command had its headquarters in Fort Lawton, Washington, and a sector headquarters located in Portland, Oregon.
- III Interceptor Command had its Atlantic regional headquarters in Wilmington, Delaware, with sector headquarters located in Charleston, South Carolina; and Jacksonville, Florida. Its Gulf Coast regional headquarters was in Tampa, Florida; with sector headquarters located in Miami, Florida; Mobile, Alabama; New Orleans, Houston, and San Antonio, Texas.
- IV Interceptor Command had its headquarters in Los Angeles, with a sector headquarters located in San Francisco.[23]

Then on 20 June 1941, in an historic airpower reorganization, the War Department created the US Army Air Forces (AAF), commanded by General Arnold. It was an entirely new air organization comprising both the Air Corps, responsible for the support and training air commands, and an operational arm, the AAF Air Force Combat Command—a redesignation of the former General Headquarters Air Force—composed of the NAFs (figs. 5-3 and 5-4).[24]

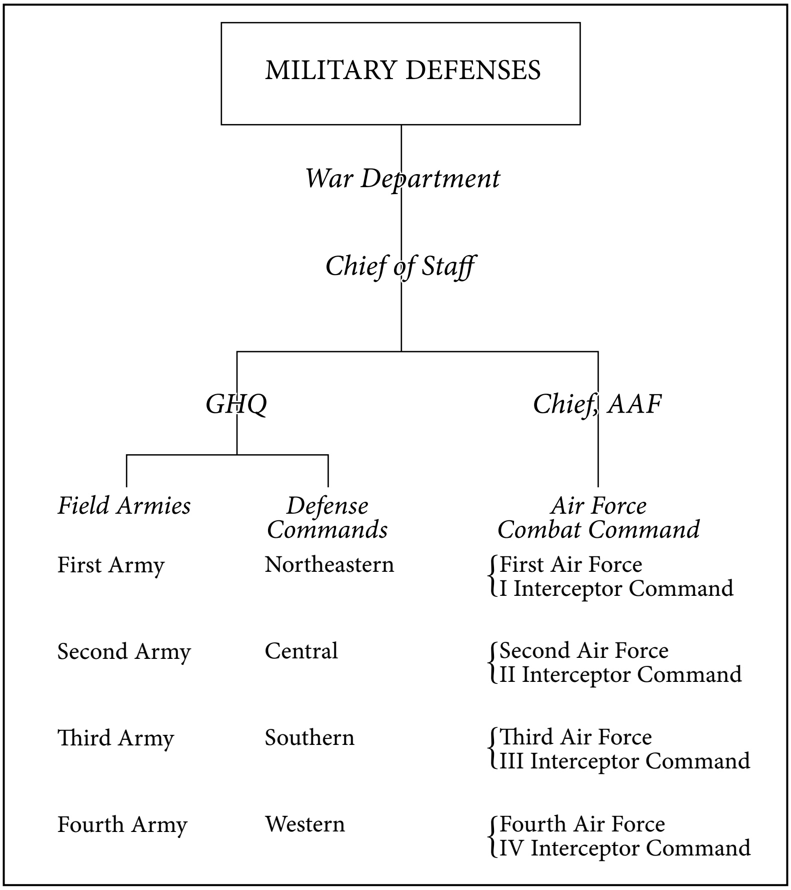

Figure 5-3. War Department reorganization, June 1941. (Reproduced from Wesley Frank Craven and James Lea Cate, eds., *The Army Air Forces in World War II*, vol. 6, *Men and Planes* [1955; new imprint, Washington, DC: Office of Air Force History, 1983], 87, http://media.defense.gov/2010/Nov/05/2001329891/-1/-1/0/AFD-101105-019.pdf.)

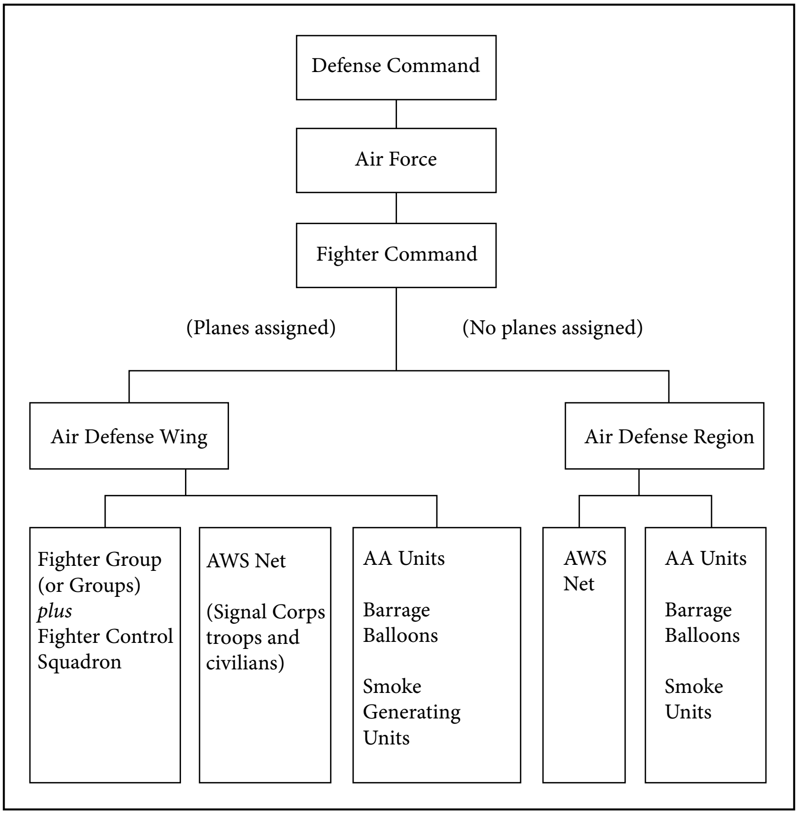

Figure 5-4. AAF air defense organization. (Reproduced from Craven and Cate, eds., *Men and Planes*, 94.)

Long the goal of airmen in the Army, the formation of a more autonomous Army Air Forces now gave the evolving AWS a command-and-control connection to its superior interceptor command. Also, the new AAF established its air staff, on which it appointed its first-ever director of air defense, the now-colonel Gordon P. Saville.[25]

Advanced Radar Training

In April 1941, Dr. James Conant, the president of Harvard University and an advisor on a host of classified technical programs, including the Manhattan Project, proposed a separate Electronic Training

Group (ETG), composed of Signal Corps and Air Corps officers with advanced engineering backgrounds. The ETG was to be gathered and sent to England to study in detail RAF Chain Home radar operations. The ETG was quickly established as a special part of the Signal Corps School. After completing basic training at Fort Monmouth, the selected officers were sent to Boston for several months to learn the electrical-engineering principles of radar at Harvard and their practical applications at the Massachusetts Institute of Technology. By the end of 1943, when the ETG program was finally discontinued, nearly 1,000 officers had received this intensive and highly selective technical training.[26]

In July 1941, the first class of 35 ETG officers began their introduction to radar, which they completed by September. Then the ETG officers were sent on to Britain. They either continued with advanced radar courses taught by British engineers or were assigned to Chain Home stations to observe air defense operations firsthand. After serving several months with the RAF, most of the officers returned to the Unites States as either expert radar planners or to train new AWS units. The ETG training proved to be a critical step for the United States to quickly gain much needed operational experience in the new art of radar warning and control.[27]

Due to the increasing numbers of AW units being prepared for overseas deployment, the demand for AWS training finally grew so large it quickly threatened to exceed the capacity of Fort Monmouth's Signal Corps School. What was needed was for the AAF and the Signal Corps to more equally share the burden of AWS training. During fall 1941, it was decided all Air Forces AWS training would be consolidated at a new Aircraft Warning Unit Training Center (AWUTC) to be built at Drew Field near Tampa, Florida.[28] This new school would soon become the largest training center of aircraft warning troops and units in the AAF, training over 6,000 AW troops at any one time.[29]

The new AWS Department at AWUTC had a staff of two officers and 12 enlisted men who were responsible for training all information and filter center specialists: the plotters, tellers, filterers, raid clerks, and so on. The new Radar Department, consisting of 19 officer and 114 enlisted instructors, conducted various SCR-268 and SCR-270 training laboratories for scope operators, radar maintenance men, power plant mechanics, platoon chiefs, and so forth.[30]

Thus, all AWS personnel now followed fixed curricula. After completing OCS, 20 percent of the officers were sent for advanced ETG training in Boston, then on to Britain. Having completed their tour with the RAF, they returned to Camp Murphy's radar school, joining the other AWS officers not requiring the ETG training. These officers also joined the enlisted radar technicians in studying the installation and maintenance of Army radar sets taught by Signal Corps instructors. After completing technical training, officer and enlisted personnel moved across Florida to Drew Field, where they joined enlisted plotters and tellers trainees to received three months training in actual air defense operations at AWUTC conducted by AAF instructors. Once this marathon of training was completed, trained officer and enlisted personnel were sent to their operational AWS units.[31]

Army Air Forces School of Applied Tactics and "Trigger"

Based on the lessons learned by the ETG officers, it became evident that an advanced air defense school was needed—not to teach more technical theory concerning the radar equipment itself but to instruct pilots and ground controllers on the more critical topic of air defense command-and-control operations and employment. At the time, Third Air Force's III Interceptor Command (III IC) was operating a school, located in Orlando, Florida, which trained their personnel from Third Air Force fighter units in combined air defense tactics. In his capacity as AAF Director of Air Defense, Colonel Saville ordered the III IC Interceptor School to conduct training of all AAF fighter pilot and controller personnel in air defense operations. The Interceptor School was renamed the Air Defense Operational Training Unit, then the Fighter Command School, and finally the Army Air Forces School of Applied Tactics (AAFSAT).[32]

The AAFSAT's Control Division was responsible for providing instruction to both pilots and controllers about AWS operations, day fighter control, night fighter GCI, and AAA employment.[33] The division developed standard operational procedures for AAF-wide use, produced tactical manuals, and tested radar equipment. It placed significant reliance on the use of "synthetic training devices"—simulated equipment and diorama tables—when aircraft were not available. Instructors were often exchanged with the Naval Radar Training School, located at St. Simons, Georgia. The Control Division also acted as the

AAF's experts in radar employment and was called upon on numerous occasions to assist the Ground Radar Branch of the Air Forces Board on AAF radar development and training.[34] The AAFSAT Control Division's Controller Course qualified officers for fixed or mobile operations at the AAF fighter command level, with an air defense command, or in a tactical air force. The Controller Course eventually grew into a program of four separate courses:[35]

The Basic Controller Course

The Basic Controller Course was the first of these courses developed. It qualified officers to be intercept officers, also known as deputy controllers, primarily in mobile radar units. There was instruction in the theory and techniques of control, with particular emphasis on practice in synthetic and actual controlling of aircraft. Also, dioramas were built, and newly devised methods introduced, using the latest reports received from AW units deployed in combat theaters of operation. The course consisted of five weeks of academic training in Orlando followed by one week of actual field operations training at nearby Leesburg, Florida, using an operational SCR-527 British GCI-type radar set in a van for mobile control training. By the end of the war, 67 classes totaling 1,336 graduates attended the Basic Controller Course.[36]

The initial class of student controllers was composed of men newly commissioned directly from civilian life and who had only two weeks of basic military training. Qualifications for controllers had been clearly defined, but the difficulty of obtaining the necessary personnel proved a problem. A very limited number of former pilots and World War I officers were available. Consequently, 40 men drawn from banks, the stock exchange, and reputable business firms were recruited and commissioned. These officers formed the nucleus of the first two courses. The initial class of 14 students began on 29 June 1942 and graduated on 8 August 1942. These 14 became the officially designated "aircraft controllers"—the forefathers of all USAF air weapons controllers, who are now known as air battle managers.[37]

The Advanced Controller Course

After several months, it was determined an additional training course was needed to enable aircraft controllers to go directly to the field to perform the duties of sector controllers with only minimal orientation in the theater of operations. The course was planned to enable students to become familiar with the most advanced types of tactical problems of aircraft control. Additional training was given in the employment and capabilities of radar, communications equipment, fixed and mobile equipment, GCI, and searchlight control systems. The course consisted of an additional three weeks of academic and actual controller training. From November 1943 until May 1944, 14 classes were conducted, graduating 174 sector controllers.[38]

The Identification Officer Course

This course consisted of four weeks of instruction in the theory of identification of target plots on filter room and operations room boards, navigation, flight plans, pre-plotting, weather, and so forth. When the last class graduated on 25 March 1944, 23 classes had been conducted, totaling 175 graduates. Also, five Women's Army Auxiliary Corps officers were trained as identification officers.[39]

The GCI Control Course—"Trigger"

Unlike the Basic Controller Course, the techniques used for GCI were much more demanding because ground-controlled intercepts usually occurred at night. The first part of the course consisted of academic instruction in the tactics of night interception using radar control of airborne interception (AI)-equipped night fighter aircraft. An SCR-527 mobile GCI-type radar set was installed by the RAF at Winter Garden, Florida. The RAF also provided a GCI advisor and a copy of their controller training syllabus, used by their own RAF Controller Training Unit at Stanmore, UK.[40]

Experienced controllers underwent four weeks of GCI training, controlling a minimum of 50 (then later 100) live interceptions using Douglas P-70 "Night Hawk" night fighters flown by the 481st Night Fighter Operational Training Group. Initially, all GCI target missions were run at pre-set altitudes on a prearranged course. However, intelligence was arriving from England that German tactics had changed and night bombers were engaging in a considerable amount of evasive action. Therefore, the prearranged procedures were discontinued, and target aircraft were then encouraged to follow their own course—making the work for the student controller even more challenging.[41]

So great was the need for GCI-capable controllers that by the end of 1943 instruction was being conducted by the school on a 24-hours-a-day, 7-days-a-week basis. In January 1944, the 481st was transferred to Hammer Field, Fresno, California. Without the night fighters, the AAFSAT GCI Course finally ended in June 1944. A total of 32 GCI classes were conducted, totaling 486 trainees, of which only 187 graduated—a 38 percent pass rate—GCI controlling was hard![42] To support the night fighter training when the 481st was transferred to California, a small temporary GCI Control Course was established at Hammer Field. It functioned there until 1947, when all GCI training was transferred to the new USAF Controller Course, was set up at Tyndall Air Force Base, Florida, in February 1948.[43] Overall, during World War II, more than 1,800 controllers were trained by AAFSAT to support a variety of AAF fixed continental air defense and mobile radar missions.

Notes

1. Terrett, *Emergency*, 172.
2. Ibid., 252.
3. Fourth Air Force, *Defense Plans and Operations*, 81.
4. Terrett, *Emergency*, 253.
5. Ibid., 256.
6. Ibid.
7. Ibid., 269.
8. Ibid., 253.
9. Thompson et al., *The Test*, 29.
10. Thompson and Harris, *Outcome*, 469.
11. Terrett, *Emergency*, 255–7.
12. Ibid., 219.
13. Thompson et al., *Test*, 102.
14. Terrett, *Emergency,* 219.
15. Thompson et al., *Test*, 97.
16. Terrett, *Emergency*, 260.
17. Greenfield, Palmer, and Wiley, *Organization of Ground Combat Troops*, 117.
18. Conn, Engelman, and Fairchild, *Guarding the United States*, 28.
19. Williams and Fellow, "Deployment of Army Air Forces," 154.
20. Ibid.
21. Williams, "Deployment of the Army Air Forces," 154.
22. History, III Fighter Command, vol. 1, 2–3.
23. Conn, Engelman, and Fairchild, *Guarding the United States*, 63.
24. Craven and Cate, eds., *Men and Planes*, 87.
25. Goss, "Air Defense of the Western Hemisphere," 254.
26. Thompson and Harris, *Outcome*, 534.
27. Terrett, *Emergency, 289.*
28. History, III Fighter Command, vol. 2, 97.
29. Thompson and Harris, *Outcome*, 538.
30. History, III Fighter Command, vol. 2, 97.

31. Thompson and Harris, *Outcome*, 534–5.
32. Schaffel, *Emerging Shield*, 41.
33. History, Controller Training Program, Air Force Historical Research Agency (AFHRA) call no. 245.5058-5 1942–1945, Inferential Research and Indexing System (IRIS) no. 00156429, 4, microfilm roll 4454 (A2660), frame 1338–49 (PDF 1317–28).
34. Ibid.
35. Ibid., frame 1338–69 (PDF 1317–48).
36. Ibid., frame 1338 (PDF 1317).
37. *First Class of Aircraft Controllers*.
38. History, Controller Training Program, Controller Training Program," AFHRA call no. 245.5058-5 1942–1945, IRIS) no. 00156429, 4, microfilm roll 4454 (A2660), frame 1325–9 (PDF 1304–8).
39. Ibid. frame 1338–41 (PDF 1317–20).
40. Ibid. frame 1329-1330 (PDF 1308–9).
41. Ibid. frame 1331 (PDF 1310).
42. Ibid. frame 1331-1338 (PDF 1310–7).
43. USAF Unit Lineage and Honors History, 3625th Technical Training Squadron.

Chapter 6

First Fighter Control Squadrons Emerge

Formation of First Units

Until fall 1941, the effort to incorporate radar into an early-warning aircraft-detection system centered on the Battle of Britain–proven RAF model. With the development of radar by the Army Signal Corps, the Army had formed signal aircraft warning (SAW) companies and battalions to operate and maintain this highly technical equipment. Each unit was to establish an air warning network of fixed radar sets. The radars were interconnected by wire communications to an information center that plotted and reported radar contacts.[1] The American AWS functioned very much like the British Chain Home radar defense.

Throughout this initial development, Air Corps aviators were detailed to work with these Signal Corps units as the controllers. As flyers, they provided critical aerial combat and ground attack expertise and could understand the intercepting pilot's viewpoint as they guided their aircraft. They spoke "air force" in a Signal Corps outfit. Once the air defense mission was transferred to the "Airmen" in March 1941, it was natural the AAF would begin thinking about forming mobile versions of the fixed SAW units.[2]

The original designation of these mobile units was "air corps squadron, interceptor control." Later they became "interceptor control squadrons." However, in May 1942, General Arnold renamed all pursuit and interceptor units as "fighter," so radar control units became "fighter control squadrons" or FCS (fig. 6-1).[3] The mission of the FCS was the tactical control of fighter aircraft in either offensive or defensive operations. The FCS used a system of radar detection sets to locate and follow friendly or hostile aircraft, radio direction finding (D/F) trucks or towers to help identify where friendly aircraft were located, "homing" stations to help aircraft steer back to base, and VHF communications relay stations to allow two-way communications.[4] VHF D/F took continuous bearings on aircraft radio emissions, especially airborne "pipsqueak" system, which radiated a signal once a minute. The bearings laid out on plotting boards at control centers served to track the planes in flight and enabled ground control officers to guide the planes by radio telephone (figs. 6-2, 6-3, and 6-4).[5]

S E C R E T :S-E-C-R-E-T :
:AUTH: CG, 11TH AF :
:INIT____, AWS, 11TH AF:
:DATE:____ :

HISTORICAL DATA

HISTORY OF 11TH FIGHTER CONTROL SQUADRON

Period covered: 24 March 1942 to 30 March 1944.

The history of the 11th Fighter Control Squadron involves both the development of VHF and this squadron as a unit. It is strongly felt by the Squadron Historian that an adequate history reflecting the true history of the squadron cannot be given the reader by merely covering the period of operation of the 11th Fighter Control Squadron from the time the said squadron landed on Adak Island, Alaska. The Historian strongly feels that it is necessary to begin the history of this squadron at the very inception of Fighter Control and VHF work in Alaska. This naturally involves some detail which will no doubt be quite interesting to the reader as the 11th Fighter Control Squadron was originally known as another organization and on proper authority of the War Department, Adjutant General's Office, the other organization's unit designation was changed, eventually to the 11th Fighter Control Squadron.

A Fighter Control Squadron is an organization assigned with a specific mission. The mission is distinctly classified as one of operations in a combat theater. The squadron has a normal complement of personnel which may be changed to some degree from time to time. The officers and enlisted men of a Fighter Control Squadron are, needless to say, specialists in their own right. The mission of operations assigned a Fighter Control Squadron is one highly technical as will be hereinafter explained. Its chief mission of operation insofar as its role to play in winning this war is concerned is to direct interceptions. In elaborating on "directing interceptions" this may be best explained by an example: When hostile radar plots definitely show that the enemy is attempting to attack a base, it is the duty of one of the specialists of the squadron, who is usually designated as a Controller or a Fighter Interceptor, to scramble a flight of fighter planes and direct the said planes to the position of the radar plots which were identified as hostile and cause our planes to intercept the enemy. When the interception has been achieved the primary mission of the Fighter Control Squadron has ceased. Its secondary missions are therefore brought forward. These secondary missions are such as informing the pilot of many and varied conditions which may arise in the course of his flight during this interception. He is to be notified of such incidentals as weather,

Figure 6-1. **"Historical Data."** (Reproduced from History, 11th Fighter Control Squadron, 24 March 1942–30 March 1944.) Declassified.

Figure 6-2. **Direction finding truck**. (Reproduced from History, 15th Fighter Control Squadron, March–May 1944.)

Figure 6-3. **Direction finding operator**. (Reproduced from History, 15th Fighter Control Squadron, March–May 1944.)

Figure 6-4. **Operation plotters charting air tracks**. (Reproduced from History, 15th Fighter Control Squadron, March–May 1944.)

Typically, the FCS was commanded by a major and had approximately 10 officers and 250 enlisted men assigned. Depending on the theater of operations, many of the FCS had Army Signal Corps SAW units attached to them to provide their critically needed radar and air/ground communications. Later in the war, however, the FCS proved itself to be self-sufficient and no longer was paired with supporting SAW companies. The standard Army FCS table of organization authorized headquarters administrative personnel, controllers, radio-A operators (radios), radio-B operators (radar), operations plotters, direction finding plotters, high frequency (HF) and very high frequency (VHF) radio monitors, HF and VHF radio repairmen, message center and teletype personnel, switchboard operators, linemen, technical supply troops, motor pool personnel, and even mess personnel. Having a mobile mission, the FCS was expected to move out and follow the war. It would set up a mobile fighter control center (FCC) that operated out of a truck to provide radio guidance to nearby fighters. However, an FCS with its FCC might be ordered to establish a theater fighter sector. The FCS would then be replaced by another incoming FCS unit. Communications were critical to fighter control—on the ground, between the FCS radar sets, radio units, and between the FCC and the fighter squadrons HQs and in the air, between FCC and airborne aircraft. Radar might have been the eyes, but it was the miles of cables and the HF/VHF radios that provided the nerves.[6]

FCSs usually were given the same number designation as their assigned fighter group. The very first FCS was not the "1st FCS." That organization was not activated until January of 1942. Instead, the very first FCS was the 24th Air Corps Squadron, Interceptor Control, at Hamilton Field, California, activated on 21 October 1941. Men arrived from across the United States, and within a month, the unit's six officers and 281 men were soon running the San Francisco Information Center, supporting the San Francisco Air Defense Wing.[7]

Next, on 1 November 1941, the 55th Air Corps Squadron, Interceptor Control, was activated at Portland Air Base, Oregon, to support the 55th Pursuit Group. It would later move north to McChord Field, near Seattle, Washington, to support the Seattle Air Defense Wing.[8] On 4 November, the 35th Air Corps Squadron, Interceptor Control, was formed, again at Hamilton Field. This unit soon sailed for the Burma–India Theater to operate under Tenth Air Force.[9] On 14 November, the 52nd Air Corps Squadron, Interceptor Control, was activated at Selfridge Field, Michigan, part of the 52nd Pursuit Group. The unit soon moved to South Carolina, then North Carolina, and then eventually to Orlando, Florida, to support the newly organizing AAFSAT.[10] On 20 November, the 20th Air Corps Squadron, Interceptor Control, was formed in Orlando for additional AAFSAT support.[11] Finally, on 1 December 1941, the 54th Air Corps Squadron, Interceptor Control, was activated at Paine Field, Everett, Washington. The unit was ordered to Baton Rouge, Louisiana, then moved on to Florida to support the Orlando Air Defense Wing.[12] Overall, by the end of World War II, nearly 70 FCSs were organized to help win the war.[13] As can be seen, however, a week before America's tragic entry into the war, the AAF had only activated six FCS units, all of which were still in the process of getting organized.

Initial Air Defense Deployments

From late 1937 onward, the threat to US national security, as viewed by both President Roosevelt and his Secretary of State, Cordell Hull, was that Germany, in combination with Japan, might achieve domination over Europe and Asia, wreck the British Commonwealth of Nations, and threaten the Western Hemisphere. In January 1939, with the specter of war looming larger over Europe, President Roosevelt warned the nation about the new range and speed of offense. Then, current German bombers could not strike directly from Europe to the United States. However, the aerial stepping stones between Norway and New England could be Iceland, Greenland, and Newfoundland, Canada. Likewise, the Germans could reach into the south Western Hemisphere from Brazil, via Africa. The Caribbean also constituted a U-boat and commerce-raider danger as its eastern approaches were poorly protected.[14]

In his request to Congress for additional defense appropriations for the fiscal year 1940, President Roosevelt enlarged upon these themes by identifying these new forms of attack, paying attention to offensive airpower. In the Pacific, the problem was primarily one of extending facilities in the territories of the United States. In the Atlantic, however, it meant acquiring basing privileges from Latin American and European nations. National defense was now to be thought possible through total hemisphere defense.[15]

At that time, the only US Army garrisons overseas were its small Panama, Puerto Rico, Hawaii, and Philippines departments. By 1941, the United States began backing up its hemisphere defense intentions by increased deployments of American troops to those departments deploying troops to other strategically critical locations. As a show of US resolve, Secretary of War Henry L. Stimson began the deployment of several task forces. In February 1941, Task Forces 1 and 2 were approved to deploy to the Caribbean, while Task Force 3 was to deploy to Newfoundland. Task Force 2 was sent to Jamaica in April, and an agreement with the Danish government was signed approving the deployment of US troops to Greenland. Later, in August, Task Force 4 was dispatched to Iceland. With each of these task forces came its pursuit aircraft and AW companies; invariably the AWSs arrived without their scarce radar equipment.[16] By the end of 1941—only two years after the War Department created its trial Signal Company, Aircraft Warning, Panama, radar unit—efforts were underway for the new AAF to build and deploy numerous air defense units around the globe.

Continental Air Defense

During fall 1941, the four theater interceptor commands worked feverishly to create a coastal radar net and operational AWS. Radar was made operational in San Francisco, Seattle, and in New York City—with the help of RCA Corporation technicians.[17] Sites for 13 radar stations along the East Coast had been picked, and eight stations were approaching completion by December. On the West Coast, 10 radar stations guarded the 1,200 miles stretching from Seattle to San Diego. However, there were not enough trained personnel to operate the equipment, no GCI radar capability, no VHF radio sites, and no identification-friend-or-foe sets (fig. 6-5).[18]

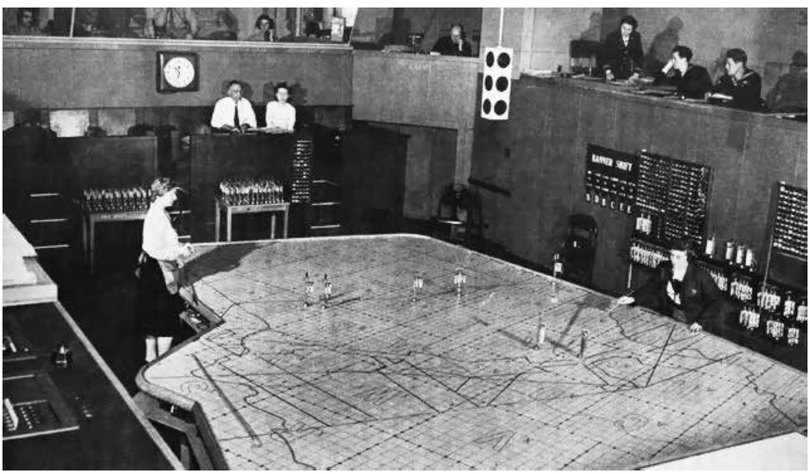

Figure 6-5. **Philadelphia Information Center, 1940**. (Reproduced from Wesley Frank Craven and James Lea Cate, eds., *Army Air Forces in World War II*, vol. 1, *Plans and Early Operations* [Chicago: University of Chicago Press, 1950], 289.)

Caribbean Air Defense

At the same time, the War Department was organizing its continental air defense efforts. Plans were also being made to unite the Panama Canal Department, the Puerto Rico Department, and several British islands under a new, single Caribbean Defense Command (CDC).[19] Headquarters for CDC were established at Quarry Heights, Panama, across from Albrook Field and the pursuit planes of the 19th Composite Wing. By summer 1941, Puerto Rico's San Juan Information Center had one SCR-270 operating 24 hours a day. It also had three SCR-271s on hand, but they were not operational due to lack of parts.[20] By November, the Signal Company, AW, Panama, had two operational radars in service, an SCR-270 at each end of the canal, operating 24 hours a day (fig. 6-6).[21]

Figure 6-6. **SCR-270 mobile radar in Panama**. (Reprinted from Rebecca Robbins Raines, *Getting the Message Through: A Branch History of the U.S. Army Signal Corps* [Honolulu: University Press of the Pacific, 2005], 234.)

North Atlantic Air Defense

Establishing a secure air route to Great Britain was one of the War Department's highest priorities, so the first Air Corps forces began arriving in Newfoundland in October 1940. Acting as the staging point for most of the aircraft traffic to Europe, Task Force 3's critical Newfoundland Aircraft Warning Service had three SCR-270s in operation by spring 1941.[22] Meanwhile, one officer and 26 enlisted men of the 1st Aircraft Warning Company, fresh from Fort Hancock, New Jersey, arrived at Greenland's Bluie West Army Air Field in July 1941. They were to begin convoy and ferry aircraft protection and to support friendly forces patrolling against Luftwaffe overflight. The overflights were facilitating the establishment of weather stations to support German operations in the North Atlantic.[23] Germany staged several air attacks against the British forces stationed in Iceland in February 1941. Responding to these attacks, 30 P-40s of the 33rd Pursuit Squadron arrived in Reykjavik at the end of August with its 33rd Aircraft Warning Company and several SCR-268s and SCR-270s. Task Force 4 had a 24-hour fighter control room in operation by that fall, and by December, three RAF radar stations had been deployed and were operational (fig. 6-7).[24]

Figure 6-7. **SCR-268 radar in Greenland**. (Reproduced from Thompson, Harris, Oakes, and Terrett, *The Test*, 292.)

Alaskan Air Defense

In February 1941, all US troops in Alaska, under the Alaskan Defense Force, were now renamed the Alaska Defense Command. That same month, the 18th Pursuit Squadron, flying P-36s, arrived at Elmendorf Field to work with B-18 bombers. The next month, the Signal

Company, Aircraft Warning, Alaska, arrived at Fort Richardson.[25] The Alaska Defense Command consisted of only 143 troops, a dozen or so aircraft, and no radar sets for its AW company. The Army had intended to develop an AWS in Alaska as soon as it could, having begun work back in summer 1940. By October, a new plan had been approved, calling for 20 stations to be built throughout Alaska. However, by December 1941 none of them were completed or in operation. The overall goal had been too optimistic. No one had realized what a tremendously difficult job it would be to install and maintain radar sets in such rugged, isolated locations.[26]

Philippines Air Defense

With the threat of Japanese attack imminent, the War Department undertook a massive effort to accelerate the delivery of 100 new aircraft—B-17 and B-24 bombers and P-35 and P-40 fighters—to the Far East Air Forces for the defense of the islands. The Signal Company, Aircraft Warning, Philippines Department, arrived in August of 1941 to Fort William McKinley, in Manila, but without any AW equipment.[27] However, by October, a single SCR-270 radar had been established at Iba Field, 75 miles northwest of Manila. Although seven radar sets had reached the Philippines by December 1941, only two—one at Iba and another one outside Manila—were operational.[28]

Hawaiian Air Defense

The Signal Company, Aircraft Warning, Hawaii, had 13 officers and 348 enlisted men, under the command of Capt Wilfred Tetley.[29] The company operated a rudimentary information center at Fort Shafter in the hills above Honolulu. The unit's first SCR-270s had arrived in July 1941, and by September, five sets were operating around the rim of Oahu. A sixth, at the Opana site on the northern point of Oahu at Kahuku Point, had just joined the AWS in November and had a range of approximately 75–125 miles seaward. Exercises that same month had detected aircraft carrier aircraft operating at 80 miles out to sea. However, due to a shortage of spare parts, most radars were only operated from 0400–0700 hours daily, when the concern for an attack seemed the greatest (fig. 6-8). Understanding that an AWS was critical, the operations officer of the Hawaiian Interceptor Command, Col Kenneth Berquist, and his Signal Corps officer, Lt Col Carroll Powell, visited the mainland to witness a IV Interceptor

Command AWS exercise. They returned to Hawaii on 4 December 1941 to begin building their aircraft warning system.[30]

Figure 6-8. **Opana Radar Station**. (Reproduced from Andrew McKinley "The Opana Radar Station: Before the Attack," Pearl Harbor Visitors Bureau, 2 June 2016, https://visitpearlharbor.org/the-opana-radar-station/.)

Overall, the building of new overseas air defense aircraft warning services had been a monumental task and was just in its infancy. Nothing like it had ever been attempted before by the Army, on such a large scale, over such global distances. Having established a tentative early warning and pursuit fighter capability in the Caribbean, North Atlantic, the Philippines, to some extent in Alaska, but certainly in Hawaii, the War Department air defense planners were optimistic these early efforts had been successful. On 7 December 1941, they would be proven terribly wrong.

Radar and the Attack on Pearl Harbor

On that Sunday morning, two trucks and a trailer holding the SCR-270 radar were parked on Opana Hill. Parked parallel to each other, the trucks contained the transmitter, receiver, oscilloscope, and operator equipment. On the trailer was mounted the 50-foot tall radar antenna.[31]

Suddenly, at 0702 hours, Pvt George Elliott and Pvt Joseph Lockard, practicing with their radar set, detected many aircraft approaching Oahu from the north. Elliott and Lockard quickly reported their findings to the information center at Fort Shafter. However, since this report arrived after the designated 3-hour watch time, most of the information center staff had already gone to breakfast. On duty that morning was Lt Kermit Tyler, a pilot with the 78th Pursuit Squadron, on loan from Wheeler Field. He had been in the information center only once before. After receiving Lockard's report, Tyler reasoned the radar returns were a flight of Army B-17s arriving from San Francisco that morning. As a result, Tyler instructed the Opana radar unit to disregard the returns and to not worry about it.

Intrigued, Elliott and Lockard continued to plot the incoming aircraft until 0740 hours, when they lost the contacts. They then secured their radar equipment and headed down the hill for breakfast. It was only upon arriving for breakfast that the learned the Japanese air attack was under way (fig. 6-9).[32] Overall, this was more of a failure of organization than of technology. The radar had successfully detected the incoming Japanese fighters, and Privates Elliott and Lockard had correctly detected and reported them. However, the immature Hawaiian AWS had not successfully functioned as an integrated air defense system, superiors had not been informed, and Army aircraft were not scrambled to engage the enemy—in fact they remained on the ground and were destroyed during the sudden attack.

Conclusion

Despite this early failure, the importance of radar detection and the need for an AWS to quickly and accurately alert air defense forces was immediately recognized. The use of this invention called radar gave a protecting force the ability to mount a timely defense against an enemy air attack. The theoretical concept of using radio frequencies to detect aircraft had become a reality in just 10 years. The "science" of radar and the "art" of air defense were combined in this way. The story of the beginnings of radar and fighter control is made up of innovative and persistent individuals, of teams of engineers building a vision, and of professional military officers in a race to employ a fantastic new technology to face a rapidly growing threat.

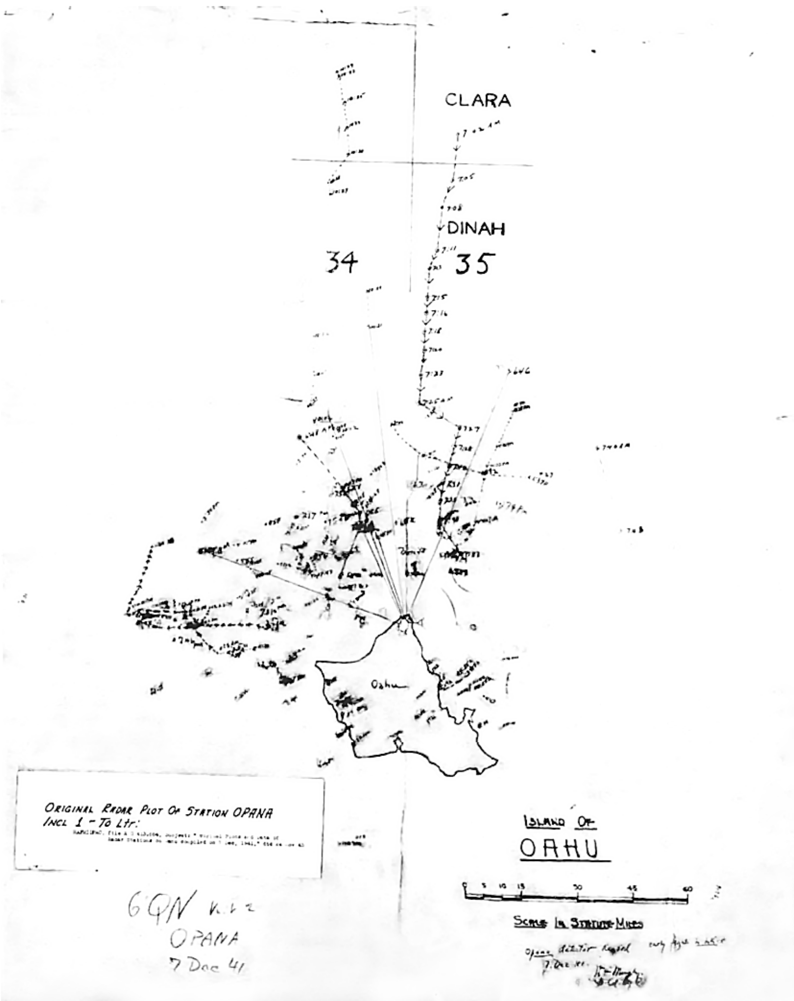

Figure 6-9. **Opana radar plot, 7 Dec 1941**. (Reproduced from Thompson, Harris, Oakes, and Terrett, *The Test*, 8.)

Notes

1. Terrett, *Emergency*, 150.
2. Craven and Cate, *Army Air Forces in World War II*, vol. 6, *Men and Planes*, 154.
3. Ibid., 307.
4. Terrett, *Emergency*, Signal Corps Equipment Appendix, 307–42.
5. Thompson and Harris, *Outcome,* 648.
6. Terrett, *Emergency*, 149–50.
7. History, 23rd Fighter Control Squadrons (FCS), Air Force Historical Research Agency (AFHRA) call no. SQ-FI-CONTL-24-HI October 1941–February 1944, "Headquarters 4th Air Force General orders No. 49," 21 October 1941, and 1, microfilm roll 0879 (A0830), (PDF frames 460–61).
8. History, 55th FCS, AFHRA call no. SQ-FI-CONTL-55-HI November 1941–September 1942, "Organization History," 30 September 1942, microfilm roll 0881 (A0832), frame 685 (PDF frame 651).
9. History, 35th FCS, AFHRA call no. SQ-FI-CONTL-35-HI November 1941–August 1944, "Organization History," 13 January 1943, microfilm roll 0879 (A0830), (PDF frame 838).
10. History, 52nd FCS, AFHRA call no. SQ-FI-CONTL-52-HI June 1943, "Unit History," 1 July 1944, 39, microfilm roll 0879 (A0831), frame 1691 (PDF frame 1573).
11. History, 52nd FCS, AFHRA call no. SQ-FI-CONTL-52-HI June 1943, "Annex A-1 to Field Order 270," 85th Fighter Wing, 1, microfilm roll 0878 (A0829), (PDF frame 1907).
12. History, 54th FCS, AFHRA call no. SQ-FI-CONTL-54-HI December 1941–January 1944, "History," 17 January 1944, 1, microfilm roll 0881 (A0832), frame 548 (PDF frame 518).
13. *Fighter Control Squadrons*, USAF Historical Division.
14. Cate, "Air Corps Prepares for War," 118.
15. Ibid.
16. Terrett, *Emergency*, 208.
17. Prange, *Pearl Harbor*, 366.
18. Goss, "Air Defense," 290–91.
19. Conn, Engelman, and Fairchild, *Guarding the United States*, 329.
20. Terrett, *Emergency*, 299.
21. Prange, *Pearl Harbor*, 366.
22. Terrett, *Emergency*, 281.
23. Cate, "Air Corps Prepares for War," 122.
24. Terrett, *Emergency*, 279.
25. Ibid., 208.
26. Conn, Engelman, and Fairchild, *Guarding the United States*, 245–57.
27. Hoyt, *Airmen*, 41.
28. Williams and Fellow, "Deployment of Army Air Forces," 186.
29. Terrett, *Emergency*, 305.
30. Conn, Engelman, and Fairchild, *Guarding the United States*, 167–68.
31. Butowsky, "Opana Radar Site," 4. http://focus.nps.gov/pdfhost/docs/NHLS/Text/91001379.pdf.
32. Ibid., 8–9.

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Now, 25 years later, retired Lieutenant Colonel DeGering's outstanding research effort is finally available in book form for a much wider audience.

The biggest problem of modern fighters was intelligence. Without a continuous stream of accurate information keeping the fighters posted on exactly where the high-speed bombers were, attempts at interception were like hunting needles in a limitless haystack.

—Capt Claire "Flying Tigers" Chennault

During the 1930s, as World War II approached, the US Army began an urgent effort to construct an effective air-defense strategy. Its greatest problem—how to quickly detect approaching enemy bombers, then accurately control interceptors to the bombers before targets were attacked?

The solution—radar! First developed by the British Royal Air Force in the 1930s, this new, top secret, and utterly amazing technical capability would provide the operational intelligence so desperately needed by newly forming Army Air Forces fighter control squadrons.

How was radar first developed? When was it first employed to direct fighter aircraft against approaching enemy air forces? Could the Army Signal Corps duplicate the RAF's technical achievement? How did the Army Signal Corps and Army Air Forces work together to develop the nation's first air warning services? Could radar sets be delivered to radar units in time for the approaching war? In his well-researched book, the author outlines the beginnings of Army radar development and its first operational uses for tactical fighter control.

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