The Roots of the Command and Control of Air Power: An Appraisal of Three Air Forces Through 1945

by

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A dissertation presented to the faculty of Air University
in partial fulfillment of the requirements for the degree of Doctor of Philosophy
Maxwell Air Force Base, Alabama

17 September 2014

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Introduction

To paraphrase Martin van Creveld, commanding and controlling forces has been around since time immemorial and a failure to have effective command and control is "to court disaster."[1] It is no different for warfare in the third domain. Effective command and control of air forces improves a commander's ability to make and execute good decisions in a timely manner. It provides unity of effort[2], massing of forces as necessary, and flexibility to react to battlefield dynamics.

Nations, and specifically their military services, continuously evaluate their environment and make strategic decisions regarding force composition. In the next decade, the United States Air Force (USAF) will face many challenges. One is ensuring an appropriate command and control system for a changing and evolving Air Force. Command and control of air forces is seldom thought of or discussed until needed, and then usually as an afterthought. Unlike aircraft, which are the highly visible symbols of airpower, command and control is generally unseen. It operates in the background, ignored until it is unavailable or fails. Two exceptions in history are the Battle of Britain and the USAF since 2002 when General John P. Jumper formally designated the Air Operations Center a weapons system. In the former case, command and control was at least as important as the aircraft involved. In the latter instance, making a command and control center at the operational level of war a weapon system, equivalent to fighters or bombers, highlights the importance, centrality, and criticality of command and control in modern warfare. In the current fiscal environment, a mission not as "glamorous" as flying is easily neglected in the search for "savings." History suggests this would be inadvisable—command and control is airpower's sinew.

[1] Martin Van Creveld, *Command in War* (Cambridge, Mass: Harvard University Press, 1985), 1.
[2] See Dana J. Johnson and James A. Winnefeld, *Joint Air Operations: Pursuit of Unity in Command and Control, 1942-1991* (Annapolis, Md: Naval Institute Press, 1993).

Without it the structure has no connectivity. Discussions regarding air forces and their successes and failures generally revolve around a myriad of other topics such as strategy, doctrine, battles, aircraft quality, or production rates. A holistic examination of effective command and control of air forces is missing from the literature.

No comparative historical studies exist examining how air forces developed command and control systems. How does an air force integrate organization, processes, and technology into a command and control construct? How and what concepts of command and control did each of these nations develop? When and why did each of these nations develop command and control mechanisms for their Air Forces in light of the operational realities each of them faced? Were they effective? To what extent are the concepts and principles that had evolved through 1945 still relevant today?

This work utilizes the case study method, which provides a holistic view of past events to help answer the "what," "how," "when," and "why" questions posed earlier. This qualitative methodology provides a means to collect data from a specific timeframe, examine the context of the data, and evaluate the processes used. The approach considers both the phenomena (command and control of airpower) and the context (the strategic environment). Specifically, this study compares and contrasts three national (British, American, and German) approaches to command and control of airpower through World War II. It examines the commonalities and differences between the countries and their unique approaches to the problem of commanding and controlling air forces. It will also hopefully offer insights into the larger question of how national air forces often develop along different lines.

Unlike Van Creveld this study will use the term command and control throughout because it more richly conveys what the study is attempting to describe, which is not only having command authority, but the ability to control as required throughout battle.

Before going further, command and control requires a formal definition. This study uses the one provided in United States Joint Publication (JP) 1-02 as it provides a very succinct definition. It defines command as "the authority that a commander in the armed forces lawfully exercises over subordinates by virtue of rank or assignment." The modern US definition of control is tied to various types of control regarding command authority; "authority that may be less than full command exercised by a commander over part of the activities of subordinate or other organizations." This study defines control as simply the ability to direct forces. The two together in fact create the modern US joint definition for command and control, "the exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission."[3]

Commanders require a system to exercise direction and authority over their forces to give them the ability to collect, process, share, and communicate information quickly. Of course, information also requires protection. As we will see, effective command and control of air forces relies on communications; without it, all the information available is as helpful as no information. The eighteenth century balloon pioneers the Montgolfier brothers, with no military background, commented on the need for a communications system to integrate with balloons and make the information they had usable to the Army.[4]

Command and control is comprised of three parts best viewed as a three-legged stool. It is composed of organization, processes, and systems (technology). To answer the research questions posed and provide a coherent synthesis, the study examines the three national approaches to command and control over three time-periods (World War I, the interwar

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[3] Joint Chiefs of Staff Washington D.C., *Department of Defense Dictionary Of Military and Associated Terms, JP 1-02* (Ft. Belvoir: Defense Technical Information Center, 2010, amended 15 March 2014), 45.

[4] Robert Grainger Ker Thompson, *The Royal Flying Corps (Per Ardua Ad Astra)* (London: H. Hamilton, 1968), 11.

period, and World War II), using three functions (organization, processes, and technology). Each of these three functions has several elements within them to provide fidelity.

Organization refers to the structure of the command and control process and includes command relationships, relationships between commanders, and training. The process leg is "how" command and control is conducted; the doctrine, tactics, techniques, and procedures. The third leg, systems, consists of the mechanisms or technology that enables command and control.

Throughout history, all three legs of the command and control stool were present. An ancient tribe had a leader with forces under his command. The leader had trained warriors and chains of commands were established. The tribe knew the processes and signals for commencing an attack, stopping an attack, and reacting to the leader's calls. Finally, the technology at this level may have simply been voice communication. As warfare became more complicated, all three legs of the stool evolved in order to command and control forces but nonetheless retained the same basic principle. That basic principle is the ability to command forces and change what they are doing on the battlefield based on inputs received by the command.

The advent of air arms presented Army leaders with the problem of integrating a new capability into an existing organization that required coordinating its activities with the whole in order to accomplish the greater organizational objective. Further, the air arm did not have a single mission, at least not for very long. No sooner had observation or reconnaissance aircraft been airborne before others realized the importance of the information they provided and attempted to shoot them down. While the capability did not exist, stories of death and destruction from above, such as those by H.G. Wells, fueled not only the public's imagination of airpower's potential but also those of military thinkers.

The need to command and control air forces grew out of almost two simultaneous needs; the need to command and control observation and artillery spotting operations and the need to defend against enemy aircraft attacking those aircraft. The air services and the antiaircraft artillery service had to work together, utilizing an integrated command and control organization, processes, and technology to be effective against attacking enemy aircraft. The command and control of offensive operations grew later and much more slowly. It would not be until WWII and especially 1944 that command and control for offensive operations peaked.

Using the methodology above, several sub-questions helps provide a coherent synthesis; how similar and different were the three functions among the nations? What accounts for the similarities and differences? What were the contextual drivers? How does an air force create effective command and control for its forces, when does it happen, and why does it occur? Did they create an effective command and control infrastructure to support their air forces as they operated in the anticipated environment? What is the significance of how a nation develops an effective command and control system? Specifically, are insights from the last war retained? How did command and control evolve? How does a nation's "view" of the environment influence the development of airpower command and control? Are the broad principles transcendent, but the specifics details changing? Did they come at the problem from a different starting point? If so, did they converge or stay on divergent lines? What was the impact of selecting either path? Was the resulting command and control system a result of a systematic evolution, or simply a reaction to the crucible of war?

There are numerous significant sources related to British, American, and German command and control during World War II. For the Royal Flying Corps (RFC) and the Royal Air Force (RAF), Walter Alexander Raleigh and H. A. Jones' official history *The War in the Air*, Denis Richards and Hilary Aldan St George Saunders' official history *Royal Air Force 1939-1945*; the Air Ministry's formerly classified official histories of RAF Fighter Command and the Battle of Britain are excellent sources. Other excellent sources include memoirs and other writings by leading figures such as Sir Winston Churchill, John Slessor, Sir General Philip Joubert de la Ferté, Admiral Murray Fraser Sueter, Sir Frederick Hugh Sykes, General E. B. Ashmore and various developers of radar. Brad William Gladman's *Intelligence and Anglo-American Air Support in World War II*, *Strategy for Victory* by David Ian Hall, and Ian Gooderson's *Air Power at the Battlefront* are also excellent sources for intelligence and air-to-ground cooperation, another aspect but less examined area of command and control. The Historical Research Agency (HRA) at Maxwell also contains documents from the British Air Ministry. Finally, the *Journal of the Royal United Services Institute*, an extremely professional and well-respected journal, provides excellent insight into airpower and joint command and control from the dawn of aircraft to World War II.

The best sources for American doctrine during the time period are *US Army in World War II* Series, *The Army Air Forces in World War II* by Wesley Frank Craven and James Lea Cate, Robert Futrell's *Ideas, concepts, doctrine: a history of basic thinking in the United States Air Force, 1907-1964*, and Maurer Maurer's work on World War I since it contains reproductions of primary documents of the period. Army doctrinal publications, the writings of various authors at the Air Corps Tactical School, and material from the various command and control schools such as the fighter control school provide a rich primary source of Air Corps airpower thought and application. Excellent secondary sources focusing mainly on air-ground integration, but still covering theater level operations include, *Air Power for Patton's Army: The XIX Tactical Air Command in the Second World War* by David Spires, *Case Studies in the Development of Close Air Support* by Benjamin Cooling, *Pattern for Joint Operations: World War 2 Close Air Support, North Africa* by Daniel Mortensen, and *The Development of Air Doctrine in the Army Air Arm 1917-1941* by Thomas Greer. The Air Corps lacked a truly professional journal for most of the period under examination, although the Air Corps News Letter provides some insight into Air Corps happenings during the time-period. Most airmen interested in publishing articles submitted their work to the *Coast Artillery Journal*. The *Coast Artillery Journal* is a professional journal like *JRUSI* and provides excellent insight into the discussions of airpower, command and control and joint operations from 1922 to 1945. Finally, the Signal Corps also published the *Signal Corps Bulletin* that began as an outlet to disseminate information, but later became a professional journal in the same vein as the *Coast Artillery Journal*.

German doctrine and control methods in WWI are best captured from Ernst Wilhelm von Hoeppner' *Germany's War in the Air: The Development and Operations of German Military Aviation in the World War*, Horst Adalbert Koch's *Flak: Die Geschichte der Deutschen Flakartillerie*, Walter von Eberhardt and Wilhelm Zickerick's *Unsere Luftstreitkräfte, 1914-1918: Ein Denkmal deutschen Heldentums*, Oberstleutnant Büdingen's *Entwicklung und Einsatz der deutschen Flakwaffe und des Luftschutzes im Weltkriege*, and Georg Paul Neumann's *Die Deutschen Luftstreitkräfte im Weltkriege*, also available in an abridged English version.

Interwar and World War II German doctrine and control methods are best captured--in English anyway--through Walter Grabman's extensive volumes on German air defense entitled *USAF Historical Studies: No. 164 German Air Force Air Defense Operations 1933-1945*, and General Joseph Kammhuber's discussion of air defense, *USAF Historical Studies: No. 179, Problems in the Conduct of a Day and Night Defensive Air War.* Additionally, Hans-Detlef Herhudt von Rohden, the official Luftwaffe historian, discusses air defense in his *European Contributions to the History of World War II, 1939-1945; The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945.* The best sources for radar technology include Louis Brown's *A Radar History of World War II*, Harry von Kroge's, *GEMA: Birthplace of German Radar and Sonar*, Werner Muller's *Ground radar systems of the German Luftwaffe to 1945,* and the Army Air Forces magazine "Radar*.*" Gebhard Aders' *History of the German Night Fighter Force, 1917- 1945* provides excellent information on both German fighter control technology and methods. *The Luftwaffe's Way of War: German Air Force Doctrine 1911-1945* by James S. Corum and Richard R. Muller provide insight into German airpower thinking from 1913 through World War II. Corum's *The Luftwaffe: Creating the Operational Air War, 1918-1940* provides valuable insight into German doctrine and specifically the attempt to fuse doctrine and technology. Muller's and Donald Caldwell's *The Luftwaffe Over Germany: Defense of the Reich* provides insight into the Luftwaffe's air defense doctrine, technology, and theories on integrating a multitude of new technologies into a command and control system to defend the Reich. Finally, *Flak: German Anti-Aircraft Defenses, 1914-1945* by Edward B. Westermann provides an in-depth look at one part of the command and control structure.

This study does not cover the details of the antagonisms and non-acceptance of the uniqueness of airpower by either the land or maritime forces of the United States or Great Britain nor the greater acceptance of airpower by the German army. Additionally, this study does not cover the details of the budgetary fights or constraints between WWI and WWII. Interservice rivalries, both doctrinally, and budgetary are covered in sufficient detail to give the reader an awareness of the environment and constraints not just of the air services, but also of the land and maritime services of each nation. Limited resources stoked interservice rivalries and affected decisions of which technologies to pursue. Germany was especially constrained by the Versailles Treaty and general economic conditions until Hitler's rise to power. Even then however, Germany did not have unlimited fiscal resources.

In summary, command and control is about the flow of information up and down the chain of command. The commander's intent must get to the units and information must flow back to the commander to allow for continuous decision-making as the battle unfolds. The cycle is continuous. Ineffective command and control of air forces greatly hampers operations across all domains. Air Forces must get command and control "mostly right" to avert disaster. The examination of three nations' journeys through the development of the command and control of airpower will shed light on the fundamentals of the command and control of airpower, and how preconceived notions and strategic vision shape the forces with which a nation goes to war.

Chapter 1

World War I

Before the start of World War I, the British, as with all the major nations, explored how the new airplane would affect war. Since the time of the balloon, "airpower" served to gather information to help a commander make a decision. Tentative steps before the war demonstrated the airplane's capabilities in the command and control role. Large numbers of aircraft conducting various missions and an enemy determined to stop those missions led to a need to orchestrate airpower. When war started, those tentative steps became a sprint, both on the continent and in the defense of the UK. By the end of WWI, the British had developed the concepts and system that served as the model for all subsequent US and UK command and control systems..

The United Kingdom Before The Great War

In 1890, the British War Office created the Balloon Section as part of the Royal Engineers. The invention of heavier than air flight in 1903 led to rapid changes in air power ideas that resulted in organizational changes. On 1 April 1911, a newly created Air Battalion replaced the Balloon School, consisting of a Headquarters and two companies, one for kites and balloons (Airships) and another for airplanes.[1] On 27 February 1912, the cabinet approved a report from the technical subcommittee of the Committee of Imperial Defense and requested the King's permission to establish a Royal Flying Corps (RFC) with two wings; Military and

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[1] Sir Frederick Hugh Sykes, *Aviation in Peace and War* (London: E. Arnold & Co., 1922), 19, 22.; Thompson, *The Royal Flying Corps*, 22.; Philip Joubert de la Ferté, *The Third Service; The Story Behind the Royal Air Force* (London: Thames and Hudson, 1955), 5.; Charles Frederick Snowden Gamble, *The Air Weapon, being some account of the growth of British military aeronautics from the beginnings in the year 1783 until the end of the year 1929* (London: H. Milford, Oxford University Press, 1931), 126-127.; John Howard Morrow, *The Great War in the Air: Military Aviation from 1909 to 1921* (Washington: Smithsonian Institution Press, 1993), 12.; Lee B. Kennett, *The First Air War, 1914-1918* (New York: Free Press, 1991), 8.; Walter Alexander Raleigh and H. A. Jones, *The War in the Air; Being the Story of the Part Played in the Great War by the Royal Air Force, Vol I.* (Oxford: Clarendon Press, 1922), 142.

Naval, effective 13 April 1912. The Air Battalion merged into the RFC to become the Military Wing. The Naval Wing soon referred to itself as the Royal Naval Air Service while the Military Wing simply became known as the Royal Flying Corps.[2] As in the United States, "the Corps quickly fell victim to inter-service ambition and to departmental jealousy." This lack of coordination between the Military Wing and the Royal Naval Air Service was a driving factor in the creation of the Royal Air Force (RAF) on 1 April 1918,[3] but service fighting continued throughout the 1920s, 1930s, and 1940s.

Mirroring airpower's development across all nations, reconnaissance was the airplane's original role within the RFC, but naturally other roles emerged, mainly driven by the outbreak of war in 1914; night flying, photography, artillery cooperation, bombardment, attack, and air superiority.[4]

During the French maneuvers in 1911, the British observed aircraft conducting reconnaissance, artillery controlled fire, and photography. They also noted several lessons during the Italo-Turkish War 1911-1912: "first, that thenceforth no nation could afford to go to war--as Turkey did--with a marked inferiority in aerial strength; secondly, that the use of aircraft had a great moral effect; thirdly, that aeroplanes could suffer a good deal of punishment without vital damage being inflicted to their structure; and fourthly, that the strength of an air force was largely dependent upon the efficiency of its 'ground

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[2] Gamble, *The Air Weapon*, 162-169.; "Memorandum on the Organization of the Air Services, by Lieutenant General Sir David Henderson, July 1917," *The Airpower Historian* Vol III, Number II, (July 1956): 143-145.; Sykes, *Aviation in Peace and War,* 22-23.; Thompson, *The Royal Flying Corps,* 26.; Joubert de la Ferté, *The Third Service,* 12.; Raleigh and Jones, *The War in the Air, Vol I,* 198-199.; Morrow, *The Great War in the Air,* 40.

[3] Walter Alexander Raleigh and H. A. Jones, *The War in the Air; Being the story of the part played in the Great war by the Royal Air Force, Vol V*. (Oxford: Clarendon Press, 1935), 210, 445.; Gamble, *The Air Weapon*, 169.; Sykes, *Aviation in Peace and War,* 23, 94.; Kennett, *The First Air War, 1914-1918*, 8.; Thompson, *The Royal Flying Corps,* 105.; Terence H. O'Brien, *Civil Defence* (London: H.M. Stationery Off., 1955), 9.

[4] Joubert de la Ferté, *The Third Service,* 31.; Thompson, *The Royal Flying Corps,* 24.; Sykes, *Aviation in Peace and War,* 38, 40.; Raleigh and Jones, *The War in the Air, Vol I*, 260.

organization.’”[5] Each of these four lessons influenced British airpower thinking through World War II with the fourth setting the foundation for command and control.

The French maneuvers and the Italo-Turkish War resulted in a September 1912 War Office memorandum entitled *Employment of Royal Flying Corps on Army Maneuvers*. It stated aircraft probably had a variety of uses, but its primary function is gathering information for ground forces. Maneuvers conducted that September and the Balkan War of October 1912 - May 1913 resulted in additional observations. Those observations were: 1) troops could not move without being spotted from the air, 2) the “urgent need for a quick and dependable method of communications between aircraft and ground troops, and also between the pilot and the observers,” and 3) the need to have highly trained observers.[6]

An update in 1913, *Employment*, stated the RFC-Military Wing’s main duties were to “provide special faculties for observation and the rapid communication of information” and “as a rule work under the direct orders of a general head-quarters as army troops.” It could conduct independent missions or be detached, but should still work as a combined arms team. Maneuvers in 1913 validated the observations. Despite the lack of reference to artillery spotting in the regulations, experimentation began in August 1913 using lights and smoke bombs as a means to communicate.[7] The “rapid communication of information” required a command and control system.

Numerous debates regarding gaining air superiority or command of the air occurred within the British military before the war. Captain C. J. Burke, writing in the *Journal of the Royal United Service Institution* (JRUSI) in December 1911 believed, “there will be a struggle for the

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[5] Gamble, *The Air Weapon*, 139.; Thompson, *The Royal Flying Corps,* 24.
[6] Gamble, *The Air Weapon*, 193-197.
[7] Gamble, *The Air Weapon*, 226, 237.

supremacy of the air."[8] It was not just younger officers foreseeing the need for command of the air. A British general observed after the 1912 maneuvers, "Personally, I think there is no doubt that before land fighting takes place, we shall have to fight and destroy the enemy aircraft. It seems to me impossible for troops to fight, while the hostile aircraft are able to keep up their observation. That is to say, warfare will be impossible until we have mastery of the air."[9] Major Frederick Sykes similarly stated that command of the skies was necessary "in order to obtain information ourselves and to prevent enemy air reconnaissance from doing so."[10] Conversely, others such as Colonel Hunter-Weston questioned the ability to gain command of the air, believing hostile patrols would meet and fight, but because it was aerial warfare, both pilots would die.[11] Major General R. M. Ruck writing in June 1914 did not see the possibility of getting command of the air, viewing the primary defense against attack as attacking the enemy.[12] This very thought would be the foundation of British doctrinal thought through World War II. Nonetheless, air forces had already begun actively discussing the concept of having to control the air or at least deny it to others.

The British were aware of French and German efforts to arm their aircraft. In 1912, Lieutenant F.L.M. Boothby discussed the need to arm aircraft in order to drive away other aircraft so observation aircraft could conduct their mission.[13] The British began exploring various options in January 1913. The first tests, conducted on 27 November 1913, used an American Lewis gun from a basket hung underneath the aircraft to shoot

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[8] C. J. Burke, Captain, "The Aeroplane as an Aid to the Solution of Existing Strategical Problems," *Journal of the Royal United Services Institution* Vol LV (December 1911): 1627.; Great Britain. *Offence versus Defence in the Air*. ([S.l.]: Printed in France by A.P. and S.S. Press, 1917), 1.
[9] Kennett, *The First Air War, 1914-1918*, 64.
[10] Kennett, *The First Air War, 1914-1918*, 64.
[11] Burke, "The Aeroplane as an Aid to the Solution of Existing Strategical Problems," 1634.
[12] Louis Jackson, Colonel, "The Defence of Localities Against Aerial Attack," *Journal of the Royal United Services Institution* Vol LVIII (June 1914): 720.
[13] F. L. M. Boothby, Lieutenant, "Aircraft for Sea Service," *Journal of the Royal United Services Institution* Vol LVI (June 1912): 752.

at a ground target.[14] By October 1913, the opinion of the Secretary of War was a matter of official record; the reconnaissance mission required mastery of the air.[15] By the time World War I began, despite the primary mission being reconnaissance, the British military discussed and explored other missions.

The United Kingdom During the Great War

Organization

Initially, Major General Sir David Henderson commanded the RFC in France until August 1915, when Brigadier General Sir Hugh Trenchard took command.[16] The commander of the RFC had a dual role; to command the air forces and to serve at the General Headquarters as the lead air advisor to the Commander–in-Chief. The air force commander was to be co-located near the Commander-in-Chief to develop the air plan in conjunction with the military commanders. With an overall plan developed for the main objective, the air units planned the details in support of the military operation.[17]

Despite working closely with ground commanders and de-emphasizing independent air operations, the British Army Corps and then Army Commanders each wanted air forces to be "at their disposal for observation and photography," exhibiting, in the words of Air Chief Marshal Sir Philip Joubert de la Ferte, a "private air force" mentality. This led to a dispersion of air power and inability to concentrate when needed to affect the battlefield. He perceived that the Germans did not experience this problem, noting British Army Commanders should have understood "the principle of war, 'Concentrate at the decisive point and time' was just as applicable to the RFC as to the Army."[18] RFC

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[14] Gamble, *The Air Weapon*, 244.
[15] Gamble, *The Air Weapon*, 245.
[16] Joubert de la Ferté, *The Third Service,* 31-32.
[17] John Slessor, *Air Power and Armies* (Tuscaloosa: University of Alabama Press, 2009), 87-88.
[18] Joubert de la Ferté, *The Third Service,* 34-35.; Raleigh and Jones, *The War in the Air, Vol I*, 434.

Headquarters retained command and control of the strategic reconnaissance and bombardment missions,[19] while Corps Squadrons conducting observation and artillery spotting were allocated to the Corps.[20] This prevented the parceling of air power into what was then already termed “penny packets,” allowing the Army to control airpower needed for direct observation and artillery spotting, while the RFC concentrated the remaining airpower to conduct offensive operations, bombing, or localized air superiority missions.[21]

0n the home front, Sir Winston Churchill took it upon himself and the Admiralty to provide for home defense since “something must be done. We cannot have Zeppelins sitting over Whitehall dropping bombs. It is a War Office responsibility, I know. But, they have all their work cut out to keep the Army going in France. They are strained to the utmost, and I am quite certain they can give this matter no attention, nor can they spare the men.”[22] Hence, beginning in September 1914 the Admiralty led the defense of Great Britain from air attack.[23] It had experience in this area. In 1912, the RNAS set up sea stations along the coast and the Admiralty, then also under Churchill, set three aircraft requirements; an overseas plane that could be launched from a ship, a scouting plane, and a home service plane to repel any enemy.[24] On 10 September 1915, the Admiralty consolidated all anti-aircraft artillery (AAA) under a single commander. Unlike the RFC, the RNAS believed AAA and searchlights were sufficient for defense, viewing the aircraft as having a subordinate role mainly due to standing airborne patrols being

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[19] Joubert de la Ferté, *The Third Service,* 35.
[20] Great Britain, *Offence versus Defence in the Air*, 1.; Raleigh and Jones, *The War in the Air, Vol I,* 331.; Slessor, *Air Power and Armies*, 87.
[21] Thompson, *The Royal Flying Corps,* 85-87.
[22] Murray Fraser Sueter, *Airmen or Noahs; Fair Play for our Airmen; The Great "Neon" Air Myth Exposed*. (London: Sir I. Pitman & Sons, 1928), 163.
[23] Edward Bailey Ashmore, *Air Defence*. (London: Longmans, Green and Co., 1929), 18.; Morrow, *The Great War in the Air,* 118.; Christopher Cole and E. F. Cheesman, *The Air Defence of Britain 1914-1918* (London: Putnam, 1984), 8.
[24] Raleigh and Jones, *The War in the Air, Vol I*, 264-265.

too costly in terms of fuel, maintenance and manning.[25] This was a step backwards from an earlier Admiralty policy in 1912 of using aircraft for home defense purposes.[26] The RNAS did not think of using a command and control system to detect enemy aircraft and communicate information to aircraft on alert. This defensive schema relying only on searchlights and AAA proved ineffective.

Public fears of an attack by German Zeppelins on London became reality, resulting in the creation of the London Air Defence Area (LADA) in late 1915.[27] The War Office and Admiralty continuously fought over who should control the important Home Defense and Air Defense mission.[28] Infighting and inefficiencies led to consolidation on 16 February 1916, with Home Air Defense transferred to the Army under Field Marshal Lord John Denton Pinkstone French, Commander-in-Chief, Home Forces.[29]

The Admiralty relinquished control of aircraft defense and a new anti-aircraft section came into being, responsible for home defense, intelligence, AAA, and searchlights.[30] At the end of 1916, AAA and searchlights within the London Area fell under a single commander, Lord French. Previously, they resided under seven subordinate commanders under the General Officer Commander (GOC) London District for training and under Lord French, the Field-Marshal Commanding-in-Chief for operations.[31] Now, as with all other Home Defense units across the United Kingdom, they reported to a single commander.

Despite the continued and gradual improvements in air defense and the underlying command and control structure,

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[25] Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 37.
[26] Raleigh and Jones, *The War in the Air, Vol I*, 264-265.
[27] Joubert de la Ferté, *The Third Service,* 44.
[28] Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 33.
[29] O'Brien, *Civil Defence*, 7-8.; Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 7-8, 154.; Ashmore, *Air Defence,* 18-19.
[30] Ashmore, *Air Defence,* 18-19.
[31] Raleigh and Jones, *The War in the Air, Vol V*, 5-6.; Frederick Arthur Pile, *Ack-ack: Britain's Defence Against Air Attack during the Second World War* (London: Harrap, 1949), 47.

> On 7 July, 1917, a flotilla of German aircraft raided London in broad daylight, serenely, insolently, with practically complete impunity. That raid led more than any other single event to the transformation of the Air Board into the Air Ministry which we have today. It was one of the big, dramatic, decisive incidents in history.[32]

This event left an indelible mark on the British, serving as the spark to the creation of a new command and control system for airpower. Because of the raid, the British established a committee led by Lieutenant General J.C. Smuts to examine air defense.[33] The Smuts Committee released a two-part report on 19 July 1917, the first on air defense, and the second regarding a future independent air service. It recommended a single officer with air experience under Commander-in-Chief Home Forces to command LADA, the consolidation of AAA, aircraft, searchlights, observation posts, and the ability to control them to repel an attack.[34] That officer was Brigadier General E. B. Ashmore, appointed on 5 August 1917.[35] He remained the leader of a unified command and control system for the defense of Great Britain for the rest of the war.

Processes

From almost the beginning, the British viewed offensive operations as the best use of airpower and the best way to achieve air superiority to enable other operations; offense is the best defense.[36] Churchill expressed the concept of "forward air defense" in his 5 September 1914 Air Defense Memorandum stating, "the great defence against aerial menace is to attack the enemy's aircraft as near as possible to their point

[32] J. M. Spaight, *The Beginnings of Organised Air Power; A Historical Study* (London: Longmans, Green and Co., 1927), 121.
[33] Joubert de la Ferté, *The Third Service,* 48.
[34] Scot Robertson, *The Development of RAF Strategic Bombing Doctrine, 1919-1939* (Westport, Conn: Praeger, 1995), 17.; Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 219.
[35] Joubert de la Ferté, *The Third Service,* 49, 53.; Raleigh and Jones, *The War in the Air, Vol V*, 43.; Alfred Rawlinson, *The Defence of London, 1915-1918* (London: A. Melrose, 1923), 225.; Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 221.
[36] Sykes, *Aviation in Peace and War,* 88.

of departure." He called for forward bases in France to attack German airfields, to be in constant telephone and telegraph contact with overseas squadrons, and have an intercepting force interconnected with communications.[37] Churchill clearly enunciated the need for a command and control system.

The prevailing thought was "no defence, however skillfully arranged, can prevent some of the attacking aircraft from getting through and reaching the vicinity of their objective. The modern aeroplane is possessed of great range, great speed, is an exceedingly accurate weapon, and is not easily intercepted."[38] Aviators thought the sky too big to defend, and if the enemy knew an area had defenses, it would simply attack another area.[39] Even with enough aircraft for both offensive and defensive operations, aviators of the time thought attacking aircraft would still get through.[40] This idea may be the reason for Trenchard's offensive doctrine.[41] Sir Philip Joubert de la Ferte claims Trenchard did not initially support strategic bombing or independent air operations over providing support to ground troops.[42]

Experience confirmed the British doctrinal concept of the offensive-defensive and the difficulty of the defense against air attack. During the first year of the war, aircraft or AAA destroyed not a single Zeppelin, but attacks destroyed six in their sheds.[43] In fact, firebombs released from above a Zeppelin over Ghent brought down the first Zeppelin because at the time, British defensive aircraft did not have guns.[44] The Battle of the

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[37] Winston Churchill, *The World Crisis* (New York: Scribner, 1931), 341-342.
[38] Sueter, *Airmen or Noahs,* 176.
[39] Maurice Baring, *Flying Corps Headquarters, 1914-1918* (Edinburgh: Blackwood, 1968), 182.; Great Britain, *Offence versus Defence in the Air, 3*.
[40] Great Britain, *Offence versus Defence in the Air,* 3.; Baring, *Flying Corps Headquarters, 1914-1918,* 182.
[41] Kennett, *The First Air War, 1914-1918*, 77.
[42] Joubert de la Ferté, *The Third Service,* 69.
[43] Barry D. Powers, *Strategy Without Slide-rule: British Air Strategy, 1914-1939* (London: Croom Helm, 1976), 28-29.
[44] Arch Whitehouse, *The Years of the Sky Kings* (Garden City, N.Y.: Doubleday, 1959), 90.; Sueter, *Airmen or Noahs,* 14.

Somme demonstrated that concentration and offensive action led to air superiority and air superiority in turn was a tremendous benefit to ground operations.[45] All these events seemed to confirm prewar doctrinal concepts.

Interestingly, in Volume V of the official history, written in 1935, H. A. Jones described the airplane as an offensive weapon. He acknowledged the need for defensive aircraft, but used defensively, the aircraft just became another anti-aircraft weapon. In defense, the aircraft had no initiative, limited in scope by its radios. Finally, "that is to say, the only defense in the air likely to be effective in the long run is an offensive more powerfully sustained than that conducted by the enemy."[46] Jones clearly disregarded the role aircraft played in the defense of Great Britain in the First World War probably because the idea of using aircraft in a defensive schema did not fit the doctrinal construct the RAF and Air Ministry wanted to shape during the inter-war period. The concept of offensive operations for defensive purposes would continue to dominate British thinking and planning through World War II and nearly preventing the development of the robust command and control system that saved Great Britain from defeat.

Events on 22 August 1914 highlight the value of airpower and an effective command and control system to ground forces, for it was RFC reconnaissance flights that discovered the advance of General Alexander von Kluck's German First Army near Mons, Belgium. Early in the war, General Douglas Haig also relied on aircraft noting on 7 September 1914, "I sent reconnaissance by aeroplane wide on the East and NE. They returned at 7 am and said fog in the valley prevented them from seeing.

[45] Thompson, *The Royal Flying Corps,* 85-86.; E. R. Hooton, *War Over the Trenches: Air Power and Western Front Campaigns 1916-1918* (Hersham: Midland, 201), 124.
[46] Raleigh and Jones, *The War in the Air, Vol V,* 158-159.

But by 10 am they gave me useful information showing the Germans all on the move northwards except some Cavalry & guns."[47]

As the war progressed, command and control grew in importance. Prior to the war, support to ground troops was not heavily explored. In 1915, the RFC conducted experiments with contact patrols to provide direct support to ground troops, but did not employ them until the Battle of the Somme in July 1916.[48] Contact patrols helped commanders track attacks and enemy reactions, and relayed messages to keep information flowing between front-line units and headquarters, proving especially helpful when telegraph lines were cut due to artillery fire.[49] Contact patrols eventually evolved to attacking enemy ground troops with machine guns.[50] While contact planes were effective, air-ground coordination was not good. The introduction of tanks led to new attempts at coordination with aircraft via wireless, but those proved impractical due to the state of wireless technology.[51]

Other aircraft worked directly with artillery. Despite some early experiments before the war with artillery spotting, by early 1915, air and artillery cooperation was still problematic.[52] To improve cooperation and improve the flow of information, the RFC created liaisons between aircraft and artillery units.[53] Aircraft, infantry, and artillery communicated with flares, lamps, panels, message bags, klaxon horns, signal sheets, Morse code, and wireless.[54]

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[47] G. D. Sheffield, and Daniel Todman, *Command and Control on the Western Front: The British Army's Experience, 1914-1918* (Staplehurst: Spellmount, 2002), 17-18.
[48] Walter Alexander Raleigh and H. A. Jones, *The War in the Air; Being the Story of the Part Played in the Great War by the Royal Air Force, Vol II*. (Oxford: Clarendon Press, 1928), 179-180.
[49] Great Britain, *Offence versus Defence in the Air*, 3, 5.; Sykes, *Aviation in Peace and War,* 64-65.; Sheffield and Todman, *Command and Control on the Western Front,* 124.
[50] Sykes, *Aviation in Peace and War,* 64-65.
[51] Thompson, *The Royal Flying Corps,* 261, 269.
[52] Thompson, *The Royal Flying Corps,* 49.
[53] Sheffield and Todman, *Command and Control on the Western Front,* 129.
[54] Sykes, *Aviation in Peace and War,* 64-65.; Sheffield and Todman, *Command and Control on the Western Front,* 124, 129.

The idea to defend against aircraft with other aircraft along the frontier using an efficient telephone service to coordinate action did not emerge because of war; those discussions took place as early as 1911.[55] Nonetheless, war propelled theoretical discussions into a plan of action. Air services on both sides quickly learned the advantages of a command and control system for defense by creating elaborate warning systems; spotters relayed information, sending reports by telephone to plotting centers and then to fighter units.[56] In France, the aircraft and anti-artillery services worked together to defeat enemy air attacks. Aircraft on ground alert launched to repulse enemy attacks or at a minimum disrupt enemy bombardment to minimize bomb damage, after AAA listeners phoned in information on incoming enemy aircraft to aerodromes.[57] Commanders received information to include detailed maps depicting the overall air situation, similar to the following description provided in the *Coast Artillery Journal*.

> Paris Headquarters had a large map on which was kept posted data showing the locations of the invading planes so that the number of planes and routes being taken were known and followed. Batteries were located on this map by small maps; red glowing indicated that batteries were in action; blue that they had ceased firing. Another map showed the cities having antiaircraft defense throughout France, on which a similar system of red and blue lights indicated at a glance the progress of raids.[58]

This large map gave the commander a visual picture of the situation, allowing him to make critical and timely decisions regarding the defense of Paris.

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[55] Walter F. Reid, "The Use of Explosives in Aerial Warfare, With Some Remarks on Methods of Defence," *Journal of the Royal United Services Institution* Vol LV (June 1911): 741.
[56] Kennett, *The First Air War, 1914-1918*, 88.
[57] Burgo D. Gill, First Lieutenant, "Antiaircraft in the A.E.F.," *Coast Artillery Journal* (March-April, 1933): 88.
[58] Gill, "Antiaircraft in the A.E.F.," 88-89.

The development of warning systems and the integration of AAA and fighters forced German bombers into night operations in order to continue to fly with acceptable loss rates. While day bombing did not disappear, it became much more limited.[59] When day bombing did occur, Trenchard had to commit half his force to attacking enemy airfields to deal with enemy air defenses and escort his bombers to keep losses at a minimum.[60] The RFC conducted its first bombing escort mission in late 1915.[61]

These results mirror the German experience. For example, of the estimated 500 German planes sent to attack Paris, most did not succeed. Flying over allied lines triggered the early warning system spanning from the front lines to Paris, allowing the allies to blunt the air attacks on Paris.[62]

While a command and control system was sprouting on the Western Front, in Great Britain, the development of the first observer system occurred through trial and error, despite considerable pre-war thought on the subject. The British public also played a role in forcing the government to take action. Daylight raids frightened the populace, which they obviously deemed unacceptable.[63] After an attack by German airships in May 1915, London Air Defense Area (LADA) came into being in September 1915 under Admiral Sir Percy Scott.[64] LADA initially consisted of an observer screen on the coast to London, which included mobile guns and lights on the outskirts of London.[65] At first, London police bore responsibility for spotting enemy aircraft and reporting it to the Admiralty. The information then flowed to the War Office, to Scotland Yard, the Railways, and the Speaker of the House of Commons, and

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[59] Kennett, *The First Air War, 1914-1918*, 52-53.
[60] Sykes, *Aviation in Peace and War,* 90.
[61] Norman Macmillan, *Sir Sefton Brancker* (London: W. Heinemann, 1935), 110.
[62] Raleigh and Jones, *The War in the Air, Vol V*, 158.
[63] Raleigh and Jones, *The War in the Air, Vol V,* 38.
[64] Ashmore, *Air Defence,* 3-4.
[65] Joubert de la Ferté, *The Third Service,* 44.

finally to the AAA and searchlights units.[66] Later the Chief Constables in the counties assumed responsibility for observation. These observation posts kept each other and the Admiralty informed as best as possible, but congested telephones due to bad reporting procedures slowed the system down resulting in late or inaccurate information reaching the proper authorities.[67]

In Britain, the observer posts linked to a control room in the House Guards.[68] Information on enemy activity arrived at the operations room from stations, observer posts, searchlights, gun positions, or aircraft. Personnel then sorted and plotted the information and sent it to Aperfield for transmission to airborne aircraft. This system served as the forerunner of sector control.[69] In the operations room, the plotting table had aircraft symbols to help decision makers visualize the information. A painstakingly detailed manual paper record keeping system slowed the process tremendously. Information flowed more quickly once plotters used headsets and linked directly to the information centers transmitting the information.[70] While accuracy was naturally important, the British found the value of information was also highly correlated to the speed of information flow.[71]

Overall, ineffectiveness led to revisions on 25 March 1916. Great Britain had eight warning areas with a warning controller, who was the AAA commander, located at a central headquarters representing the Commander-in-Chief in each of the warning areas. Each warning area had several warning districts. The system relied on the existing telephone infrastructure to tie together the observer posts and AAA positions for

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[66] Pile, *Ack-ack,* 46-47.; Ashmore, *Air Defence,* 5.; Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 12.
[67] Ashmore, *Air Defence,* 5.; O'Brien, *Civil Defence*, 8.; E. B. Ashmore, Major-General, "Anti-Aircraft Defence," *Journal of the Royal United Services Institution* Vol LXXII (February 1927): 9.
[68] Graham Wallace, *R.A.F. Biggin Hill* (London: Putnam, 1957), 36.
[69] Wallace, *R.A.F. Biggin Hill*, 43-44.
[70] Wallace, *R.A.F. Biggin Hill*, 45-46.
[71] Raleigh and Jones, *The War in the Air, Vol I*, 247.

which the warning controller was responsible. At first, unfit soldiers operated the observer posts, but a switch to using police improved the system. This had the added benefit of tying the military defensive network to the civilian warning system.[72]

Over time, better radios, ground signaling, reporting procedures, improved massing of aircraft, and the ability to roam areas or flex as needed improved the system incrementally. Despite creating an integrated defensive command and control system, problems still existed as evidenced from the lack of AAA and fighter cooperation in defending London in May 1917 and night intercepts were still near impossible unless searchlights stayed on bombers for several minutes. No technology existed to assist with night intercepts. Nonetheless, the purpose of a well built command and control system for air defense was to make bombing prohibitively expensive and stop the attacks.[73]

Following the release of the Smuts Report, Ashmore took command of LADA based on his background in defense and command and control. On 20 October 1915, the King of England visited then Colonel Ashmore's command in France. Charged with the King's protection, Colonel Ashmore established a no fly zone over the King's lodging, protecting it with air patrols. These patrols however missed an unmarked civilian Henry-Farman aircraft that flew over the King's lodging while Colonel Ashmore watched the whole affair.[74] The event led him to conclude airplanes "are impotent in defence unless they are helped by an elaborate and far-reaching system of observation and control on the ground." From this he developed a system that included the creation of an Observer Corps, soon known as the Royal Observer Corps, connected via telephone, and using primitive sound locators.[75] Philip Joubert de la

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[72] O'Brien, *Civil Defence*, 8-9.; Ashmore, *Air Defence,* 18-19.
[73] Ashmore, *Air Defence,* 36, 124, 151.; Joubert de la Ferté, *The Third Service,* 49.
[74] Ashmore, *Air Defence,* 13.; Baring, *Flying Corps Headquarters, 1914-1918,* 113-114.
[75] Ashmore, *Air Defence,* 13.

Ferte would claim the Germans copied the system during the Great War.[76] There is no evidence however the Germans were aware of these British early warning and basic command and control concepts. In fact, Ashmore himself credits the Germans with already understanding the vital importance of command and control and applying it as early as 1916, while Britain would take another two years before getting it right.[77]

The London Air Defense Area included the "anti-aircraft commands of London, Harwich, Thames, Medway, and Dover, with the Eastern Command detached defences."[78] Upon assuming command, Ashmore created a 20 nm outer AAA zone to complement the inner AAA ring near London with aircraft patrolling between the two zones. A 25-mile ring of searchlights ran from Northumberland to Sussex to assist finding enemy aircraft before they passed through the AAA and then fighter areas. The flying squadrons controlled their aircraft, using the existing telephone lines.[79] Once airborne, fighters relied on the last known information, ground panels, and eventually wireless to make an intercept. Ashmore also had mobile AAA, RFC aircraft, and the observation posts of the Royal Observer Corps in districts east of Grantham-Portsmouth made available to him.[80]

Ashmore created a reporting system with observers to send information to a central location using the existing telephone infrastructure. All searchlights, aerodromes, and guns connected to 25 'sub-control points', each utilizing a large-scale map manned by plotters. Plotters received information and tellers told it to the next level, LADA. The sub-control points connected to LADA which utilized a large map to make strategic defensive decisions.[81]

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[76] Joubert de la Ferté, *The Third Service,* 55.; Ashmore, *Air Defence,* 13.
[77] Ashmore, *Air Defence,* 13. See Germany During the Great War in this chapter.
[78] Raleigh and Jones, *The War in the Air, Vol V*, 43-44.
[79] Pile, *Ack-ack,* 47-48.; Ashmore, *Air Defence,* 41.
[80] Raleigh and Jones, *The War in the Air, Vol V*, 43-44.
[81] Ian V. Hogg, *Anti-aircraft Artillery* (Marlborough: Crowood, 2002), 60-61.

Information arrived via telephone lines into the headquarters operations room to the duty officer. The operations room had a map with the warning districts. The maps had lights on it, similar to the one used for the defense of Paris to indicate affected areas and units. Messages went out to AAA, searchlights, and aerodromes where aircraft sat lined up on runway alert ready to launch. Upon confirmation, fighters scrambled to attempt an intercept. A second wave of aircraft launched when the first aircraft reached minimum fuel.[82]

Detection methods varied and improved remarkably over time. By 1917, the Intelligence Branch could plot raiders minute-by-minute based on information received from ground observers. Ground observers plotted enemy aircraft locations based on sight and engine sound while gun locations also had their own maps with plotters who told the information to the sub-control and command headquarters.[83] While aircraft could be airborne within 10-15 minutes of notification from the Coastal Warning Service, fighters still had a very hard time picking up aircraft.[84] Ashmore later recalled,

> the defenders left the aerodromes without organization, and once in the air received no help from the ground. The bulk of our pilots did not succeed in finding the enemy at all, and it is in this point that lies the main problem of defence. Owing to the difficulty of picking up one aeroplane from another in the air, it is essential to give information from the ground, where observation is easier and aircraft can be seen at far greater distances. And, to render this information timely and effective, a great system of ground observation, communication and control is required.[85]

[82] Ashmore, *Air Defence,* 49.
[83] Rawlinson, *The Defence of London, 1915-1918*, 176.
[84] Ashmore, *Air Defence,* 37-38.
[85] Ashmore, *Air Defence,* 38-39.

Hence, one of the greatest problems was the inability to find other aircraft in the air. To do so required constant, timely, and accurate information. Not only did aircraft need early warning to have time to take off and have space to make an intercept, it also required “a great system of observation, communication and control.”[86] Ashmore was not alone in his thinking. Trenchard also highlighted the impossibility of covering the skies with patrols, being too equipment and manpower intensive. Trenchard thought using resources in such a manner weakened airpower and that offense was the best defense. He too agreed with having a command and control system to address the current weaknesses, stating the need for “an extensive system of communications by wireless and other means.... and it is essential that there should be units of command over the system of patrols and communications.”[87]

As already seen, aircraft took off with the latest information and hoped for a successful intercept.[88] Once airborne, fighters were under no one’s control and intercepts were a matter of luck. Wireless would help solve that problem,[89] but before wireless, communication occurred through a variety of means; flags, heliographs, signaling lamps, signaling telescopes, pigeons,[90] ground panels, and radio. A ground signal system, the Ingram code, used white sheets to form dots and dashes that pilots could read from the air and get vectors. The system revolved around a Letter “T,” 20-foot wide at the top, 40 foot in length, panels 4 feet wide and 8 foot diameter dots positioned in different locations around the “T” to indicate various pre-scripted information. It was very slow and pilots

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[86] Ashmore, *Air Defence, 37*-38.
[87] Thompson, *The Royal Flying Corps,* 138-139.; Ashmore, *Air Defence,* 37.
[88] Ashmore, *Air Defence,* 39.
[89] Hogg, *Anti-aircraft artillery,* 60.
[90] Sheffield and Todman, *Command and Control on the Western Front*, 22.

needed extensive training to read the dots and dashes.[91] Ground panels helped guide fighters but were not very useful, especially at night.

Air defense aircraft also used signals within pre-arranged patrol areas in order to help mass aircraft to attack incoming bombers. The concept was to break up the formations and divert them to minimize damage. In fact, a 31 May 1917 Home Defence Group letter to units stated "Any delay a home defence pilot can cause by compelling an enemy to defend himself, or compel him to decrease his height by forcing combat upon himself will be of the greatest value to the defence organization as a whole."[92]

Despite the rapid changes, the defense was still powerless and could not properly defend against an October 1917 German bomber raid. The bomber did get through.[93] By early 1918, ground stations still could not control aircraft and AAA still engaged friendly fighters despite Ashmore's efforts at creating procedures to avoid fratricide.[94] Nonetheless, wireless had changed command and control and by the end of the war, ground control was close to a reality. The following description illustrates the impact wireless had on the command and control system.

> The introduction of R/T led to major reorganization and improvements in the LADA control and reporting system which were formally declared operational on 12 September 1918. The main feature of the central operations room at Spring Gardens, near Admiralty Arch in London, was the large table displaying a squared map surrounded by ten plotters. A dais provided a grandstand view for Ashmore, Higgins, a police representative, and a few senior operations officers. Plotters received information through telephone head-sets from 26 sub-control centres and transferred it to the map—a disc for a single

[91] Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 100-101.; Ashmore, *Air Defence,* 39.
[92] Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 211.
[93] Rawlinson, *The Defence of London, 1915-1918*, 222.
[94] Pile, *Ack-ack,* 50.; Ashmore, *Air Defence,* 41.

> enemy aircraft and a rectangle for a formation, with arrows indicating courses if known. During a prolonged rate different coloured symbols were introduced to avoid confusion. Fighters were represented by aircraft shaped counters. The sub-control centers received their reports from guns in searchlight sites, sound locators and the observation posts. Ashmore had a switchboard enabling him to cut into plotters' lines should he require further information or to issue instructions to a sub-commander and Higgins had direct lines to his fighter wings.[95]

Ashmore claimed to receive information in his operations room within 30 seconds of a sighting. This was a remarkable improvement from the earlier system. He also believed wireless increased the chance of intercept fourfold.[96]

Another experiment in August of 1917, to track enemy aircraft, involved "tracker aircraft." With a wireless telegraph system on board, tracker aircraft passed enemy aircraft location via Morse Code to ground stations for them to plot and track. Information included location by Grid Square, direction, number, and time, but no height data. At night this system did not work. Trackers did not fight, but kept a lookout. Although deemed too expensive, another system envisioned using continuous bearings to track enemy aircraft via many ground sound stations (discussed later).[97]

The British introduced air intelligence units after the Battle of the Somme to gather as much information as possible for the Army. Intelligence sections compiled reports from pilots and observers, interpreted photos, compiled maps to show enemy location, detailed maps for Contact Patrols, and created Bombardment Effect Maps that showed battery commanders the damage inflicted by their batteries.[98]

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[95] Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 456.
[96] Ashmore, *Air Defence*, 93, 95.
[97] Cole and Cheesman, *The Air Defence of Britain 1914-1918, 224*-225, 316.; Ashmore, *Air Defence*, 42.
[98] Sueter, *Airmen or Noahs*, 109.

They also supplemented the RFC's early warning network of observers with intelligence. Before the war, the British had foreseen the ability to intercept and exploit radio communications. They therefore prepared for the eventuality with code[99] and developed procedures to exploit German radio. "Compass Station," the Army's radio intercept units, intercepted German radio transmissions before and during battles and were used to conduct intercepts. Information on enemy air activity flowed from these stations to Army headquarters and then via telephone to aerodromes to scramble fighters. Beginning in November 1916, once airborne, ground controllers with cloth panels directed the fighters.[100]

The command and control failure at the Battle of Amiens led to the creation of an offensive version of the Compass Stations called the Central Information Bureau (CIB). It monitored enemy air activity, used the information to conduct intercepts, and provided information to contact aircraft either via visual means or radio. It also kept aircraft on alert with an average time over target of about one hour. American forces praised the system and the timeliness.[101]

Technology

Sound Detectors

A way to detect and track an aircraft accurately while also being portable, rugged, and easy to use by the average soldier[102] became the fundamental requirement to not only provide for an effective defense, but also to direct aircraft for a more effective offense. It took almost 20 years to develop such a device; listening devices were an intermediary step.

Listening devices or sound locaters were first used in WWI and initially the only practical way to detect aircraft outside visual range.

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[99] Wallace, *R.A.F. Biggin Hill*, 26.; Sheffield and Todman, *Command and Control on the Western Front*, 22.; Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 193.

[100] Hooton, *War Over the Trenches,* 119, 148.

[101] Hooton, *War Over the Trenches,* 201, 262-263.

[102] William Sackville, Captain and J. E. Olivares, Lieutenant, "A Suggestion for a New Method of Locating Aircraft at Night," *Coast Artillery Journal* (May 1927): 411-412.

They were a means to give gunners more time to prepare for a shot and assist in locating aircraft at night.[103] The French were the leading developers of the technology, transitioning through various types that focused incoming sound to pinpoint direction.[104] These devices worked on the principle of detecting a difference in the phase of sound waves.[105] Sound locators functioned by using the binaural sense. For example, "when a normal person hears a sound, he instantly knows, within 10 degrees, the direction from which it comes."[106] The sound locator used the binaural function to allow an operator to determine the angular position of an aircraft and approximate its distance. Sound detectors function because approximately half of the sound emitted from aircraft emanates from the wings, struts, and propellers and the other half from the engine. Shutting off the engine and gliding, a tactic used, did not eliminate aircraft noise.[107]

By the end of the war, all belligerents used them extensively to chart aircraft raids, especially at night. Listening posts were set up around important areas to detect aircraft noise, proving especially helpful in bad weather and at night.[108] The most used device during and immediately after WWI, the Perrin Telesitemeter, had a claimed mean error of only .13 degrees, making it the most accurate device.[109] Four types of sound locators existed: large diaphragms where microphones collected the sound, parabolic reflectors or sound mirrors, multiple coned devices, and the exponential horn. The diaphragm, reflectors, and sound

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[103] Raleigh and Jones, *The War in the Air, Vol V,* 73-74.; Hogg, *Anti-aircraft Artillery,* 23.
[104] Hiram B. Ely, Lieutenant, "Sound Locators: Their Functions and Limitations," *Coast Artillery Journal* (August 1926): 123.
[105] J. C. Haw, Major, "Antiaircraft Defense," *Coast Artillery Journal* (October 1925): 320-321. & Aaron Bradshaw, Captain, "Recent Developments in Antiaircraft Material," *Coast Artillery Journal* (May 1923): 451.
[106] Sperry Gyroscope Company, Inc., *Anti-aircraft Searchlights and Sound Locators* (Brooklyn, N.Y., 1930), 38.
[107] Sperry Gyroscope Company, Inc., *Anti-aircraft Searchlights and Sound Locators,* 37-38.
[108] Ely, "Sound Locators: Their Functions and Limitations," 123.
[109] Haw, "Antiaircraft Defense," 320-321.

mirrors were generally large, immobile, and the microphones of the time fragile. The multiple cone collector lost energy as the sound progressed through long tubes. The exponential horn was small enough to transport and retain much of the sound energy[110] and would be what most countries relied on until the advent of radar.

Night attacks drove sound locator development, with the first sound detectors built for the defense of London in 1915.[111] The first listening device was a pole with two megaphones or trumpets on each end of it at right angles, amplifying sound seven to ten times. A tube ran down from each megaphone to a man with a stethoscope. A compass affixed to the center and pivot point indicted bearing after a man, usually a blind man, turned, and then stopped when the sound was strongest. Only home defense, not the front, used blind men. Adding vertical mounted megaphones gave elevation. These devices had about a 5-mile detection range and an accuracy of about .58 degrees.[112]

Some systems had as many as 24 trumpets to help collect sound from aircraft out to 10,000 yards.[113] The French attempted to build smaller parabolic reflectors with microphones, but could only get 5-6 miles detection range with these devices.[114] In another attempt to increase detection range, Professor T. Mather and J. T. Irving cut a 16-ft diameter parabolic reflector into a chalk quarry in Kent. Tests in July 1915 indicated this device could pick up aircraft 10 miles away. Nonetheless, it was not good enough for the War Office to purchase.[115]

[110] Sperry Gyroscope Company, Inc., *Anti-aircraft Searchlights and Sound Locators*, 39-40.
[111] Hogg, *Anti-aircraft Artillery,* 47.
[112] Rawlinson, *The Defence of London, 1915-1918*, 110-111.; Hogg, *Anti-aircraft Artillery,* 47-48.; William Van der Kloot, "Mirrors and Smoke: A. V. Hill, His Brigands, and the Science of Anti-aircraft Gunnery in World War I" Notes and Records of the Royal Society (July 20, 2011): 407.
[113] Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 313.
[114] Rawlinson, *The Defence of London, 1915-1918*, 110-111.; Hogg, *Anti-aircraft Artillery,* 47-48.
[115] David Zimmerman, "Tucker's Acoustical Mirrors: Aircraft Detection before Radar," *War and Society* (1997): 75.; Hogg, *Anti-aircraft Artillery,* 107-108.; Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 46-47.

In 1916, the British formally established the Anti-Aircraft Experimental Section to develop short-range acoustical devices and in June 1917 established the Acoustical Research Section to develop an electronic long-range aircraft detector for night operations.[116]

One area investigated was the use of large sound mirrors. These were large 15 feet diameter holes, cut into stone walls, covered with concrete, and connected with a 3-foot trumpet to collect the reflected sound. First used in October 1917, this device detected aircraft up to 15 miles away. Another device consisted of a 20-foot plywood disc with microphones connected to it to collect the sound. It too detected aircraft out to 15 miles at 3,000 feet.[117] Finally, Lieutenant William Tucker and W. L. Bragg, inventors of the hot microphone, built a parabolic sound reflector along the cliffs from concrete and used a microphone to capture sound reflected from the concrete.[118]

Another system used a fixed disk system that recorded ground speed and height of aircraft flying overhead and then sent the information to a central location. It consisted of concrete cylinders with sound disks and microphones. Three, placed within a mile of each other, tied into the central location. Only three systems were built during the war due to cost and effectiveness.[119] Finally, early experiments with infrared occurred during the war, but nothing came to fruition.[120] Overall, sound locaters were ineffective, however during the war and for many years after it was the only way, besides an observer corps, to provide early warning.[121]

Radios

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[116] Zimmerman, "Tucker's Acoustical Mirrors," 75.
[117] Cole and Cheesman, *The Air Defence of Britain 1914-1918,* p. 314, 343.
[118] der Kloot, "Mirrors and Smoke," 406.
[119] Zimmerman, "Tucker's Acoustical Mirrors," 77.
[120] Ashmore, *Air Defence,* 143.
[121] Rawlinson, *The Defence of London, 1915-1918*, 237.

Air-to-air and air-to-ground communication development, to include wireless, occurred before World War I.[122] Wireless stations already existed for ground-to-ground communications,[123] but were initially inadequate for successful battlefield use at the start of the war. This was due to both the state of the technology, hardware and spectrum wise, and the resistance of many within the Army with the exception of the RFC and Royal Engineers.[124] Until wireless performance improved, other early communications methods included pigeons, panels (told sector location, number of aircraft, and direction of flight), and dropped messages.[125] Morse Code was first transmitted from air-to-ground in 1910.[126]

Aware of experiments in the United States with wireless on aircraft, the British conducted more wireless experiments with aircraft in 1912, but sets were still too heavy (250 pounds) and noisy to be useful.[127] Initially, radios fit only in airships.[128] By the start of the war radio size decreased to about 75 pounds, but still filled up the entire observer's cockpit.

The radio's importance was such that Trenchard established requirements for an air-to-air radio early in the war.[129] However, the Royal Aircraft Establishment and the Post Office Research Station split responsibility for radio development.[130] After poor results from the Royal Engineers, the RFC organized a research detachment in early 1915 at Brookland, called the Wireless Testing Park, under Captain L. E. Prince,

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[122] Sheffield and Todman, *Command and Control on the Western Front,* 18.
[123] Jackson, "The Defence of Localities Against Aerial Attack," 711.
[124] Mike Bullock and Laurence A. Lyons, *Missed Signals on the Western Front: How the slow adoption of wireless restricted British strategy and operations in World War I* (Jefferson, N.C: McFarland & Co., 2010), 155-156, 183.; Joubert de la Ferté, *The Third Service,* 96.
[125] Gamble, *The Air Weapon*, 132-133.; Sykes, *Aviation in Peace and War,* 40.; Hooton, *War Over the Trenches,* 119.; Raleigh and Jones, *The War in the Air, Vol I*, 247.
[126] Gamble, *The Air Weapon*, 132-133.
[127] Boothby, "Aircraft for Sea Service," 774.; Gamble, *The Air Weapon*, 216-217.
[128] Raleigh and Jones, *The War in the Air, Vol I*, 260.
[129] Wallace, *R.A.F. Biggin Hill*, 22.
[130] Joubert de la Ferté, *The Third Service,* 96.

RFC.[131] Aircraft wireless experiments began that same year.[132] The Wireless Testing Park moved to Biggin Hill Aerodrome on 12 December 1916, becoming the Wireless Experimental Establishment at the end of 1917.[133] Its task was to develop reliable communications for air-to-air and air-to-ground operations to speed up the communications process and provide a way to direct fighters. Wireless sped up the process by an estimated threefold.[134]

By July 1915, the Wireless Testing Park at Brookland developed a working air-to-air radio. Captain Prince took a device to allow wireless-telephony or broadcast and turned it into a piece of equipment robust enough for inflight use. Then Major Hugh Dowding saw a demonstration and arranged for a visit by the Chief of Staff. The radio achieved a 20-mile range, but the High Command did not recommend its adoption. The work conducted however, did lead to ground–to-air telephony and then to air-to-air telephony. The research conducted by the RFC became so important to operations that despite the rivalry between the two flying wings, the RNAS shut down its research in 1917 to concentrate all research at Biggin Hill.[135]

Many pilots did not like the new sets; they just wanted to fly and kill Germans. The Germans on the other hand became aware of the set and offered reward money for one. The US, aware of work at Biggin Hill, received a several day tour of the Wireless Experimental Establishment. After the war, the US Navy received D/F sets from the British to accomplish the first aerial crossing of the Atlantic in 1919. Lieutenant Commander Read said the D/F equipment made the flight possible.[136]

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[131] Wallace, *R.A.F. Biggin Hill*, 17-18.
[132] Sheffield and Todman, *Command and Control on the Western Front,* 22.
[133] Wallace, *R.A.F. Biggin Hill*, 22, 27.
[134] Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 420.
[135] Wallace, *R.A.F. Biggin Hill*, 17-18, 23, 25, 28.
[136] Wallace, *R.A.F. Biggin Hill*, 23, 25, 31-32.

By early February 1916, an early prototype wireless radio receiver was developed. A transmitter on the ground could reach aircraft out to 30 miles, but aircraft still required a 150-foot trailing antenna and soundproof headsets.[137]

Sir David Henderson, director general of military aeronautics, in 1917 suggested wireless devices for all aircraft to enable air-to-ground communications because ground panels were proving ineffective. The Admiralty rejected the idea for fear the signals would jam Fleet communications,[138] especially intelligence direction-finding stations. The RFC limited transmissions from a single aircraft to reduce the effect. The weighted risk of losing information from intelligence sources weighed against being able to talk to aircraft and direct them to stop German attacks. Still, the Admiralty was against it and won the battle and therefore air defense aircraft did not use wireless.

Wireless trials in April 1918 turned into operational experimental flights.[139] By May 1918, all defensive aircraft had wireless radio and communication between air and ground was unproblematic.[140] In summer 1918, the War Office informed the Admiralty that wireless operations had been ongoing at Biggin Hill without any complaints of interference. As a result, air defense fighters were equipped with wireless that summer.[141]

Initially, wireless development for artillery was difficult, but artillery's importance drove the rapid development of workable radios so that by the Battle of Aisne on 24 September 1914 information flowed smoothly via wireless telegraphy from artillery spotters at an effective

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[137] Cole and Cheesman, *The Air Defence of Britain 1914-1918, 154-159.*
[138] Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 212.; Raleigh and Jones, *The War in the Air, Vol V*, 23.
[139] Ashmore, *Air Defence,* 84.
[140] Ashmore, *Air Defence,* 92.
[141] Cole and Cheesman, *The Air Defence of Britain 1914-1918, 154-159,* 224.

range of 10 miles. By the fall of 1915, sets were down to 20 pounds.[142] Despite the continuous innovation throughout the war, weak radio signals and tank noise made air-tank cooperation very difficult if non-existent.[143]

Telephone lines were also very valuable, but fragile. Landlines had the disadvantage of being cut, or destroyed, especially during movement or massive artillery barrages.[144] Wireless and contact planes had to maintain the flow of communication until the reestablishment of landlines.

By war's end, radio use had grown exponentially, the technology had improved tremendously, and the RFC viewed it as invaluable. Techniques and technology now allowed aircraft to operate wirelessly every 400 yards while cooperating with artillery and not jam each other due to frequency interference. Two years earlier in January 1917 aircraft required 1000-yard separation to prevent jamming.[145] Wireless radios also helped close the time lapse between observation and reporting to the ground.[146]

In 1918, all British Bristol fighters had two-way radios with plans to equip not only Bristol Fighters, but also day bombers with radios. Experiments had also begun with coordinated fighter escort for bomber operations.[147] Foretelling the future, Trenchard wanted to use radio to guide fighters to intercept enemy aircraft, but this required too high-powered radios that interfered with other radios in the sector.[148]

The command and control of airpower grew tremendously during the war. The British were quick to see the need to create a system to

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[142] Sykes, *Aviation in Peace and War,* 38.; Wallace, *R.A.F. Biggin Hill*, 17.; Thompson, *The Royal Flying Corps,* 49.; Sueter, *Airmen or Noahs,* 107.
[143] Hooton, *War Over the Trenches,* 239.
[144] Sheffield and Todman, *Command and Control on the Western Front,* 18, 20, 34.
[145] Thompson, *The Royal Flying Corps*, 65, 105.
[146] Wallace, *R.A.F. Biggin Hill*, 17.
[147] Hooton, *War Over the Trenches*, 65, 261.
[148] Hooton, *War Over the Trenches*, 148.

gather, manage, and disseminate information. Organizationally, the British built a separate command and control system focused on home defense and one for the field army. Process wise, the two systems were similar and relatively basic, but functional. The British also critically realized the system relied on a comprehensive communications network because the data needed to be accurate, but most importantly delivered quickly. As a result, the British took to finding technological solutions seriously. Formal research organizations solved problems and improved technology while existing technology such as sound locators were adopted wholesale. Overall, the basic concepts in organization, processes, and technologies set the foundation for interwar command and control development. They still exist today, albeit in a more advanced form.

The United States Before The Great War

As with the British, the US Army integrated aviation into the existing Army organizational structure, following the pattern established in 1892 of placing lighter than air aviation in the Signal Corps' Balloon Section. In 1907, the Balloon Section became the Aeronautical Division to account for both lighter and heavier than air aviation. A lack of progress in aviation resulted in a congressional inquiry that lead to the creation of the Aviation Section within the Signal Corps on 18 July 1914.[149]

Before the US's entry into World War I, the Aviation Section of the Signal Corps established several important organizational concepts, processes, and technologies. By 1914, the Air Service's role in the US Army, captured in the War Department's *Field Service Regulation 1914,* established the Air Service's roles of tactical and strategic reconnaissance

[149] Maurer Maurer. *The U.S. Air Service in World War I, Volume II* (Maxwell AFB, Ala: Albert F. Simpson Historical Research Center, 1978), 1-21.; Thomas H. Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941* (Washington, D.C.: Office of Air Force History, U.S. Air Force, 1985), 1, 149.

and observation for artillery fires. It contained but a single sentence about "preventing aerial observation by the enemy." This document received minor changes periodically until 1918. In 1915, Brigadier General George P. Scriven, Chief of the Signal Corps, released "The Services of Information, Circular No. 8." It reiterated aviation's importance to reconnaissance and connected the thoughts presented in the *Field Service Regulation 1914* about "preventing aerial observation by the enemy" by stating in the last paragraph, "the use of the aeroplane as a defense against aeroplane attack…is, of course, obvious."[150]

Aviation's role was firmly rooted in the reconnaissance and observation missions, an extension of traditional cavalry missions.[151] A 1916 supplement to a War College Division Study, "Military Aviation," conducted for the Chief of Staff regarding the use of military aviation, confirmed aviation's roles as reconnaissance and observation. The report suggested assigning aviation directly to artillery units, but also keenly asserted, based on information from the war in Europe, that control of the air was necessary for successful artillery spotting and reconnaissance. Armies achieved air superiority through offensive action using aircraft, rather than defensively with anti-aircraft artillery. The study stated that air control would be fleeting, requiring efficiency and large numbers of aircraft. The report also highlighted bombing as highly inaccurate, noting it "has not attained great results in so far as the actual destruction of material or personnel is concerned." The ideas consciously mirror British thought since some of the evidence used in the report came directly from information on the war in Europe. By 1917, the Aviation Section recognized air combat's purpose was "to get control of the air zone" to enable reconnaissance and fire control.[152]

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[150] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 23, 33, 35.
[151] Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, 3.
[152] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 1978. 49-51, 99.

The United States During the Great War

American entry into World War I brought real experience rather than reports from the war front. By war's end, American airmen, as had all belligerents, successfully established concepts and missions still used today; attaining local air superiority via offensive operations, using sweeps to clear enemy aircraft, near and close bombing escort, escort to protect returning bombardment, escorting observation planes, protecting infantry, observation, photography, using ground alert aircraft to handle a surge in enemy air activity, utilizing specialized aircraft, and placing large numbers of aircraft under a single command.[153]

Organization

American forces entered the war as the American Expeditionary Force, under the command of General John J. Pershing. Airmen quickly made their knowledge and preferences known, immediately addressing airpower's role. The first critical step was airpower's organization within the Army to include command and its roles or missions. The best known and most vocal, Colonel William "Billy" Mitchell, immediately proposed his ideas to the Chief of Staff, US Expeditionary Forces during its stand up. He recommended the creation of two air forces; one assigned to ground forces for traditional reconnaissance and observation, the other for strategic operations behind enemy lines against enemy aircraft and material. He argued, based on historical precedent, for bombardment and pursuit units to be independent similar to traditional independent cavalry versus divisional cavalry.[154] General Pershing approved the creation of an air force assigned to support ground units, but not one for strategic operations. Pershing's Headquarters approved strategic operations as needed. The designated areas to be bombed integrated into

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[153] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 213-214, 285.; Mason M. Patrick, *The United States in the Air* (Garden City, N.Y.: Doubleday, Doran and Co., 1928), 31.
[154] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 108.; James J. Hudson, *Hostile Skies* (Syracuse, NY: Syracuse University Press, 1968), 52-58.

the overall operation based on the support and importance to the ground battle.[155]

Initially, no single commander existed for the air force approved by General Pershing, resulting in a fractured command based on geography and inter-organizational feuding for command and control.[156] Colonel Mitchell commanded the front-line or Zone of Advance while Major Raynal C. Bolling commanded the Zone of the Interior (rear area). Obviously, this command arrangement created confusion so Pershing appointed Brigadier General William L Kerly, an artillery officer, as Chief of the Air Service on 3 September 1917, superior to both Mitchell and Bolling. By 12 December 1917, Benjamin D. Foulois, an airman, became Chief of the Air Service and immediately moved all administrative functions to the rear after receiving clear guidance from General Pershing directing one man to lead at the Front and one in the Rear.[157]

Finally, on 24 December 1917 General John J. Pershing created the Air Service, Expeditionary Forces and detailed the command authorities in "Command of the Air Service, Air Expeditionary Forces, General Order No 80." The Chief of the Air Service controlled all Air Service units and personnel not assigned to tactical commands, while dictating, "Air Service units of each Army Corps will be under the direct control of the Corps Air Commander;"[158] therefore the observation group assigned as a component part of each Corps came "under orders of the corps commanders."[159] Specifically,

> the units of the Air Service are organized as integral parts of larger units, divisions, army corps, armies, and the G. H. Q. Reserve. They

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[155] Hudson, *Hostile Skies,* 302.
[156] Morrow, *The Great War in the Air,* 271-272.; Hooton, *War Over the Trenches,* 218-219.
[157] Patrick, *The United States in the Air,* 8, 14-15.
[158] Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force* (Maxwell Air Force Base, Ala: Air University Press, 1989), 22.; Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 165. & Patrick, *The United States in the Air*, 15.
[159] United States. *United States Army in the World War, 1917-1919, Reports of the Commander-in-Chief, Staff Sections and Services, Vol 15* (Wash: Govt. Pr. Office, 1948), 230.

> are therefore commanded in the full sense of the word by the commanding generals of these larger units, whose decisions are executed by their General Staffs. Responsibility for the performance of the allotted task rests upon the air service officer commanding the unit or units involved. The Air Service originates and suggests employment for its units but final decision is vested in the commanding general of the larger units, of which the Air Service forms a part.

General Pershing made it clear "there is no separate chain of tactical command in the Air Service."[160]

With the inflow of more American airmen, several other changes occurred, culminating on 29 May 1918 with Brigadier General Mason M. Patrick as the Chief of the Air Service, Brigadier General Foulois as his assistant, and Brigadier General Mitchell as the Chief of the Air Service, 1st Army.[161]

Processes

Soon after America's entrance into the war, then Colonel William Mitchell visited French and British units at the Front to observe events first hand in preparation for the arrival of American troops.[162] The Air Service, obviously influenced by the Allies also relied on the allies for much of its equipment, from aircraft to radios.

Based on the clear guidance from General Pershing, the Army Air Service employed its aircraft in close liaison with the infantry. Initially, air-ground linkages did not exist, but were created and then enhanced through trial and error. Formal processes worked best, such as using liaisons between the Air Service and Divisions, however, continuous

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[160] United States. *United States Army in the World War, 1917-1919, Reports of the Commander-in-Chief, Staff Sections and Services, Vol 15,* 249-250.
[161] Hudson, *Hostile Skies,* 52-58.; Futrell, *Ideas, Concepts, Doctrine*, 22.; John F. Shiner, *Foulois and the U.S. Army Air Corps, 1931-1935* (Washington, D.C.: Office of Air Force History, United States Air Force, 1983), 9.; Patrick, *The United States in the Air*, 8.
[162] Patrick, *The United States in the Air*, 14-15.

personal relationships[163] were also important. In fact, due to signal issues with ground troops not manning radios and realizing the importance of staying in touch with aircraft, Mitchell himself went out to the front lines to instruct infantry units on the importance of being in radio contact with aircraft.[164]

The air service also formally created Attack Squadrons and Groups for direct infantry support[165] to include infantry contact patrol planes that served as liaisons for ground attack, filled in communications gaps, and provided battlefield information as needed.[166] They received orders from headquarters containing friendly and enemy lines, objectives, attack sector, nature of preparatory phase, method of attack, D-Day, H-Hour, and the number of targets via telephone, telegraph, radios and other signal methods. Airborne aircraft communicated with infantry to redirect forces as necessary or notify infantry of the timing of aircraft attacks. Aircraft also received information while over the Division Command Post and relayed messages to airdromes as needed. Most of these interactions occurred with relatively static battle lines; however, the Air Service was fully aware of mobile warfare and the need to stay connected to conduct its mission with the infantry.[167] They witnessed British attempts at tank and aircraft integration, however rudimentary, by putting radios in both.[168]

Bombing squadrons attacked hostile infantry and artillery in close cooperation with advancing infantry using contact patrols. Bombing efforts also occurred against communication and ammunition facilities,

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[163] Kennett, *The First Air War, 1914-1918*, 87.; Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 315, 334.
[164] William Mitchell, *Memoirs of World War I: "From Start to Finish of Our Greatest War"* (New York: Random House, 1960) 261-263.
[165] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 290.
[166] Kennett, *The First Air War, 1914-1918*, 211.
[167] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 215, 293, 295-299.
[168] Kennett, *The First Air War, 1914-1918*, 212.

and heavy troop concentrations. This resulted in direct material and moral assistance to the infantry during the critical stages of an attack.[169]

The Air Service viewed pursuit as offensive with its primary function to attack enemy aircraft and protect its own aircraft.[170] As Chief of the Air Service, 1st Corps, Mitchell released "Notes on the Tactical Employment of Pursuit Aviation" governing in detail pursuit's employment. Pursuit groups closely cooperated with ground troops to protect them from German air and ground troops,[171] and at the same time protected observation aircraft. The Air Service found loose escort as the best method.[172]

Finally, the close cooperation required between the air forces themselves and with multiple arms of the Army became apparent to airmen; pursuit had to cooperate with AAA for defense, defensive pursuit had to cooperate with observation units for protection,[173] while offensive pursuit escorted bombers and reconnaissance aircraft.[174] A command and control system was born from the need to coordinate these myriad activities.

The ability to communicate is a basic requirement of a command and control system and the Air Service quickly concluded the same after observing the British on the front. Successfully translating information observed from aircraft into the destruction of enemy personnel and material resulted in the development of multiple communications methods during World War I. These included dropping messages, displaying panels of various shapes and colors, by directional flying, smoke bombs, flares, messengers, and via radio.[175] The Air Service also created a formal alert radio network to pass information to AAA and

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[169] United States. *United States Army in the World War, 1917-1919, Vol 15,* 367.
[170] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 285, 352.
[171] Mitchell, *Memoirs of World War I*, 252.
[172] United States. *United States Army in the World War, 1917-1919, Vol 15,* 229-230.
[173] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 215-216.
[174] Kennett, *The First Air War, 1914-1918*, 76.
[175] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 25, 298, 345.

aircraft regarding enemy air activity, the location of enemy observation balloons, and weather conditions. This network was one of the Army's largest during the war. The Air Service Signal Officer supervised the network comprised of: (1) Air Service Commander Station, (2) Anti-Aircraft Artillery Sector Stations, (3) Searchlight Engineers Headquarters Section, (4) Pursuit Group Section, and (5) Air Division Station.[176]

Each Observation Group had an Operations Room, essentially the information center, with maps indicating positions of airdromes, balloons, and friendly air operating areas, friendly ground positions, enemy positions, a host of other information, and issued orders as required. The Operations Room quickly became the heart of the Group. The Corps Observation Group Radio Officer logged communications traffic and supervised Squadron Radio Officers who managed information and fixed the radios for their squadrons. Finally, the Pursuit Squadron was responsible for knowing the plans of the observation and bombardment squadrons it supported, such as altitude and routing. Gathering this information came via the personal relationships between the commanders and not an "Operations Center" disseminating a master air plan.[177]

Air services on both sides quickly learned the advantages of a command and control system for defense by creating elaborate warning systems; spotters relayed information and reports by telephone to plotting centers and then to fighter units.[178] In France, the aircraft and anti-artillery services worked together to defeat enemy air attackers. AAA listeners phoned in information on incoming enemy aircraft to aerodromes where aircraft on ground alert launched to repulse enemy attacks or at a minimum disrupt enemy bombardment to minimize bomb

[176] O. E. Harvel, "Air Service Alert Radio Net," *Signal Corps Bulletin*, No 9, (August 1, 1921), 5.
[177] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 286, 271-273, 323, 325-326, 354.
[178] Kennett, *The First Air War, 1914-1918*, 88.

damage.[179] The Air Service also created Surveillance Squadrons to keep an eye on enemy air activity in order to provide warning. Upon sighting an enemy, an aircraft sent a signal to warn other aircraft.[180]

The development of warning systems and integration of AAA and fighters forced bombers to move to night operations in order to continue to fly with acceptable loss rates. While day bombing did not disappear, it became much more limited.[181] As a result, the Air Service also gained exposure to night pursuit, realizing its importance for protection against night bomber attacks and the difficulty of operating at night. Locating enemy aircraft at night was one of the greatest problems of night aviation despite the cooperation between searchlights, pursuit, and AAA.[182]

Following the British example, by 1918 the Signal Corps had established listening posts to monitor enemy radio activity. These posts, established along the front, triangulated radio traffic to pinpoint enemy positions to produce an enemy order of battle, provide evidence of enemy movement or withdrawal, and correlate enemy artillery fire to enhance the effectiveness of counter battery fire.[183] The Signal Corp monitored both German air and ground units.

Airplane stations effectively located enemy aircraft working with artillery, enabling US pursuit aircraft to interfere with them and slow them down.[184] Listening in on German weather stations also provided information on German air activity. As German ground stations took DF bearings of their airships and passed it in the open to the navigator to help him get to the target, US airplane stations intercepted the

[179] Gill, "Antiaircraft in the A.E.F.," 88.
[180] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 215, 278.
[181] Kennett, *The First Air War, 1914-1918*, 52-53.
[182] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 377-378.
[183] United States, *Final Report of the Radio Intelligence Section, General Staff, General Headquarters, American Expeditionary Forces* (Washington: U.S. Govt. Print. Off, 1935), 1-2, 35.
[184] United States, *Final Report of the Radio Intelligence Section,* 20.; Unknown Author, "The Origination and Evolution of Radio Traffic Analysis: The World War I Era," *Cryptologic Quarterly*, Vol. 6, No. 1 (Spring 1987), 28-29.

information.[185] Listening control stations then passed location and direction of flight information directly to pursuit squadrons. Finally, listening to US traffic provided insight into what the Germans were picking up and allowed the US to correct lapses in their own communications security.[186]

Overall, radio intelligence operations proved beneficial. A report issued at the end of the war recommended directly connecting intelligence stations monitoring enemy aircraft communications to the counter battery-reporting center in order to relay the information quickly to pursuit groups.[187] The US realized a good command and control system required good information on enemy activity.

Technology

The Signal Corps from early on was aware of the need to have aviation communicate with the ground. Balloons used flags, lights, pigeons, cable to telephone, and even a raised antenna to receive wireless signals. By 1905, the Signal Corps was using wireless telegraph between St Michael and Nome, Alaska across the 117 mile Norton Sound. These early devices however were big and bulking machines, barely mobile. Interestingly, Captain William Mitchell believed that by 1905 the Germans had adopted wireless field equipment as standard.[188]

In the early stages of the war, some radios had only one-way communications from the air to the ground. Aircraft noise also hampered the communication process.[189] Nonetheless, the US quickly adopted radios for their obvious flexibility, becoming the standard communication method by 1915.[190] In 1916, the Signal Corps conducted successful two-

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[185] Unknown Author, "The Origination and Evolution of Radio Traffic Analysis: The World War I Era," 27, 35.
[186] United States, *Final Report of the Radio Intelligence Section,* 2-3, 20.
[187] Unknown Author, "The Origination and Evolution of Radio Traffic Analysis: The World War I Era," 39.
[188] William Mitchell, *2nd Lecture on Field Signal Communications* ([Fort Leavenworth]: Infantry and Cavalry School, 1905), 10, 19.
[189] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 63.
[190] Kennett, *The First Air War, 1914-1918*, 34.

way communication tests between aircraft and ground units and between aircraft. They were not without their problems. Frequency interference, as happened with the British, occurred with many aircraft in an area so the US developed procedures to allow aircraft in an area to communicate with artillery and infantry units. Solutions included time deconfliction of radio transmission and increasing the frequencies available.[191]

The US entered the war late and despite having explored airpower and wireless before the war, the US benefited from their allies' experience. Upon arrival in France, the US fit into the already existing allied system, adopted their processes, and relied on their allies for much of their equipment. By the end of the war, the US knew of the importance of a command and control system for both air defense and supporting ground operations. Soon after the war however, this knowledge quickly faded from institutional memory.

Germany Before The Great War

As with the British and American Armies, the Prussian Army explored ways to exploit the balloon, the airship, and finally the airplane. On 1 June 1884, it created a *Luftschiffer* (Airship) Detachment under the *Allgemeinen Kriegsdepartment Eisenbahntruppen* (General War Department for Railroad Troops) to evaluate balloons for reconnaissance and test its ability to aid with artillery fires. The creation of a *Luftschiffer* Detachment served as the foundation for the *Luftstreitkraefte*, created later in 1916.[192] The Detachment became the *Luftschiffer Abteilung* on 1 April 1887 and the *Luftschiffer Battalion* on 1 October 1901 after commencing airship experiments in 1900.[193] A newly created

[191] Maurer Maurer, *The U.S. Air Service in World War I, Volume II*, 177-180, 205-207.
[192] Germany, *Die Militärluftfahrt bis zum Beginn des Weltkrieges 1914* (Berlin: E.S. Mittler, 1941), 5.
[193] Germany, *Die Militärluftfahrt bis zum Beginn des Weltkrieges 1914*, 10, 20.; Ernst Wilhelm von Hoeppner, *Germany's War in the Air: The Development and Operations of German Military Aviation in the World War* (Nashville, Tenn: Battery Press, 1994), 1; Alex Imrie, *Pictorial History of the German*

Funkentelegraphie (Telegraphy) Detachment fell under the *Luftschiffer Battalion* to further the use of radio equipment.[194] The German War Ministry also had a transportation department to deal with aeronautical issues while a third organization, the Inspectorate of Transport Troops, independent of the General Staff, but subject to the War Ministry, had a Research Unit and Airship Battalion. In 1906, after conferences held by the War Ministry and General Staff to determine airpower's future,[195] the Inspectorate decided to focus on airships, mostly Zeppelin dirigibles,[196] leading in May 1907 to the creation of the *Luftschiffer Abteilung der Versuchstabteilung der Verkehrstruppen* (Airship Department for Experiments of the Transport Troops).[197]

Airpower's potential for reconnaissance and communications led the General Staff in January 1908 to create a technical section, the *Sachgebiet fuer Luftschifferwesen bei der Versuchsabteilung der Verkehrstruppen* (Field Subject for Airship Knowledge in the Experimental Department of the Transport Troops) in order to make better decisions regarding new inventions and projects, placing a single officer in charge of the unit. The unit observed and evaluated worldwide airship, aircraft, motorized transportation, and radiotelegraph developments.[198] This section became part of the mobilization section under Captain Erich Ludendorff in October 1908.[199] Despite viewing the airship as the best technical option, Germany finally purchased its first aircraft in 1910.[200] On 19 October 1910, Germany made its first

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Army Air Service 1914-1918 (London: Allan, 1971), 11.; John Howard Morrow, *Building German Airpower, 1909-1914* (Knoxville: University of Tennessee Press, 1976), 14.

[194] Germany, *Die Militärluftfahrt bis zum Beginn des Weltkrieges 1914*, 21.

[195] Imrie, *Pictorial History of the German Army Air Service 1914-1918,* 11.

[196] Morrow, *Building German Airpower, 1909-1914,* 14-16.

[197] Morrow, *Building German Airpower, 1909-1914,* 14-15.; Imrie, *Pictorial History of the German Army Air Service 1914-1918,* 12.

[198] Germany, *Die Militärluftfahrt bis zum Beginn des Weltkrieges 1914*, 135-137.

[199] Morrow, *Building German airpower, 1909-1914,* 15.; Morrow, *German Air Power in World War I*, 5.

[200] Peter Kilduff, *Germany's First Air Force, 1914-1918* (London: Arms and Armour, 1991), 9.; Imrie, *Pictorial History of the German Army Air Service 1914-1918,* 15.

observance of troops from an aircraft with an airplane, proving the military value of aircraft.[201] By "March 1911, the General Staff had gained the impression from the performance of airships and aviators during the imperial maneuvers, from artillery practice against aircraft, and through information relative to the advances made by France in military aeronautics, that aviation material should be assembled and that the role of aircraft as a means of reconnaissance be taken up and further developed."[202] By 1 October 1912, all existing aviation merged to become the *Fliegertruppe* (Flying Force)[203] to handle the military and technical training of the flying troops. It dissolved one year later, replaced by the *Inspektion der Fliegertruppe* (Inspectorate of the Flying Force) led by Oberst Walter von Eberhardt and the *Inspektion der Luftschiffertruppen* (Inspectorate of the Airship Service).[204] These two Inspectorates fell under the *Inspekteurs des Militaer-Luft und Kraft-Fahrwesens* (Inspector of Military Air and Vehicles), under the *General Inspektion des Militaer Verkehrswesen* (General Inspector of Military Transportation). Many thought the dissolution of the *Fliegertruppe* into two subcomponents a move backwards, raising the call for a unified structure.

Germany entered the World War without unity of control[205] and as a result, during the early stages of World War I many questions about airpower's ability went unanswered. In reality, many believed that after a few weeks of war and the meeting of great air armadas, there would not

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[201] Germany, *Die Militärluftfahrt bis zum Beginn des Weltkrieges 1914*, 147.
[202] Hoeppner, *Germany's War in the Air,* 2.; Paul Deichmann, *USAF Historical Studies: No. 163 German Air Force operations in support of the Army* (USAF Historical Division Research Studies Institute, Air University, Maxwell AFB, Alabama, 1968), 6.
[203] Kilduff, *Germany's First Air Force, 1914-1918*, 9.
[204] Germany, *Die Militärluftfahrt bis zum Beginn des Weltkrieges 1914*, 181, 209-210.; Kilduff, *Germany's First Air Force, 1914-1918*, 10.; Imrie, *Pictorial History of the German Army Air Service 1914-1918,* 19.
[205] Germany, *Die Militärluftfahrt bis zum Beginn des Weltkrieges 1914*, 209-210.

be any aircraft left with which to fight.[206] Profound growth and changes in organization, process, and technology marked the German experience in World War I.

Germany During the Great War

Organization

Germany entered the war on 1 August 1914 with 254 pilots and 271 observers out of 4 million troops.[207] By the end of the war, Germany had approximately 5,500 airmen on active duty, another 5,500 in training or conducting other air services.[208] Despite the myriad of changes in organization from 1884 to 1912, more changes occurred when organizational deficiencies emerged in the forge of war.

As early as 1914, Oberst Walter von Eberhardt attempted to reorganize the *Fliegertruppe* and proposed a *Chef des Feldflugwesens* (Chief of Field Aviation) that had a staff officer at each *Armee* reporting to the *Chef*, but the *Oberste Heeresleitung (OHL)* (Supreme Army Command) did not approve his suggestion.[209] It took experience on the battlefield for a reorganization to occur on 11 March 1915 with Major Hermann von der Lieth-Thomsen's appointment. As cooperation between air and ground forces increased, *Gruppenfuehrer der Flieger (Grufl)* (Air Force liaisons) were attached to *Armee-Oberkommandos* (army headquarters) at the front to plan the employment of the *Feldflieger Abteilungen*, still under the operational command of the assigned field army.[210] These liaison officers reported to the Chief of Aviation and linked the army corps staff

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[206] Walter von Eberhardt, and Wilhelm Zickerick, *Unsere Luftstreitkräfte, 1914-18* (Berlin: C.A. Weller, 1930), 451.
[207] Kennett, *The First Air War, 1914-1918*, 83-84.; Kilduff, *Germany's First Air Force, 1914-1918*, 10.
[208] Georg Paul Neumann and John Everard Gurdon, *The German Air Force in the Great War* (London: Hodder and Stoughton Ltd., 1921), 51-52.
[209] Kilduff, *Germany's First Air Force, 1914-1918*, 10.
[210] Hoeppner, *Germany's War in the Air,* 34.; Kilduff, *Germany's First Air Force, 1914-1918*, 11.; Imrie, *Pictorial History of the German Army Air Service 1914-1918,* 26-27.; Neumann and Gurdon, *The German Air Force in the Great War* 1921, 198.; Imrie, *Pictorial History of the German Army Air Service 1914-1918,* 38.; Kennett, *The First Air War, 1914-1918*, 85.

and the reconnaissance squadrons.[211] At first, they only advised on technical matters, but soon provided tactical advice.[212] Poor battlefield performance also forced the centralization of German aviation under the *Chef des Feldflugwesens (Feldflugchef)* on 26 April 1915 to handle all aerial matters such as equipping and arming aircraft. The *Chef des Feldflugwesens* controlled aircraft, but did not command them; that function remained under the Army High Command.[213]

Germany minimally explored *Luftschutz* or air defense before the war. Nonetheless, Germany did not plan for a large air defense organization and had planned for *Fliegertruppe* and *Abwehrinformationen* development over a much longer time horizon.[214] War sped up development as it does so many things. Despite associating air defense and early warning, the German military did not associate the need for a communications system, an organization to provide the early warning, or the integration of AAA and aircraft. When war broke out, Ludendorff demanded defense support, but did not get it.[215] Many major changes occur only after a disaster or setback; air defense and a command and control system for Germany is an example of forced change.

Initially, "the training and direction of air defense units came under the local authorities and garrison commanders." Germany realized the importance of an early warning system after an attack on Friedrichshafen in November 1914. Border troops saw the incoming attacking planes and telephoned the warning.[216] It was however, a

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[211] Kennett, *The First Air War, 1914-1918*, 86.; Morrow, *German Air Power in World War I*, 36-37.; Morrow, *The Great War in the Air,* 104.

[212] Hoeppner, *Germany's War in the Air,* 40.

[213] Kennett, *The First Air War, 1914-1918*, 86.; Morrow, *German Air Power in World War I*, 36-37.; Morrow, *The Great War in the Air,* 104.; Kilduff, *Germany's First Air Force, 1914-1918*, 11.; Imrie, *Pictorial History of the German Army Air Service 1914-1918,* 26-27.

[214] von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 452; Wolfgang Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege* (Berlin: E.S. Mittler, 1938), 54.

[215] von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 452.

[216] Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege*, 55.

successful allied air attack on Freiburg in December 1914 that sparked the creation of a defense and early warning system.[217] Some consolidation occurred and air defense responsibility now fell to the second-in-command to the commanding general of a district, yet control of AAA still resided with the Chief of Ordnance. Overall, the system was poorly equipped and both home defense and the front line units needing the few anti-aircraft pieces available.[218]

Ballonabwehrkanone (BAK), the forerunner to *Flugluftabwehrkanone* (FLAK), was initially given to field artillery and made mobile due to the German way of war, *Bewegungskrieg* [mobile warfare]; to save money, no static guns were built. Initially, while the Germans were still practicing *Bewegungskrieg*, BAK received orders from *General-Kommandos* under the divisions, but once the war shifted to *Stellungskrieg* (positional warfare), BAK received orders from the Army headquarters. In 1915, the growing need for BAK led to the creation of a BAK officer under the Inspector of BAK of OHL whose primary duties were to advance and improve AAA operations.[219]

At war's outbreak, Germany had only 18 BAKs to protect important points such as bridges, 138 by April 1915, and the first formal AAA battery at Frankfurt-am-Main by autumn 1915.[220] In early 1915, to solidify its defenses, Germany attempted to create a solid line of defense, but with only 138 BAK it could not be done. *Gruppen* moved to fill in gaps left by BAK.[221]

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[217] Neumann and Gurdon, *The German Air Force in the Great War,* 280.; Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege,* 55.; Hoeppner, *Germany's War in the Air,* 31.
[218] Hoeppner, *Germany's War in the Air,* 32, 58-59.
[219] von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 451-452.
[220] von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 451.; Kennett, *The First Air War, 1914-1918*, 52.; Hoeppner, *Germany's War in the Air,* 30.
[221] von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 452.

By September 1915 a double AAA line ran from Lake Constance to the North Sea.[222] By January 1916, a solid line of air defense existed, with one line along the front, broken up into three sections (Ghent to Diedenhofen, Antwerp to Trier, and Maubeuge to Arlon), and the second line at a depth of 2-3 km behind the front line.[223] This defense included a double line of searchlights.[224] Germany also created air-warning districts, called *Luftsperrabteilungen*.[225]

As with the British, Germany had to find a balance for AAA between the front and home defense due to public demand.[226] Initially, low manning and training impacted the command and control process, especially the speed of information flow. The early system relied on existing sentries and telephone lines.[227] Training and infrastructure improvements came later. Due to daily exposure, AAA personnel on the front were the most experienced regarding early warning. The home front troops were not as good due not only to the lack of exposure, but also to the lack of personnel and formal training.[228] Civilians used in the early warning system as observers could not tell apart German and Allied aircraft.[229] Despite limited integration between the front and home defense the system improved over time, was successful, and remained in place throughout the war.[230]

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[222] Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege,* 58.; Hoeppner, *Germany's War in the Air,* 62-64.
[223] von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 454.; Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege,* 52.
[224] von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 456.
[225] Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege, 58.;* von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 454.
[226] Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege, 56.;* von Hoeppner, *Germany's War in the Air,* 43.
[227] von Hoeppner, *Germany's War in the Air,* 32, 58-59.
[228] Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege,* 54.
[229] von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 456.; Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege,* 56.
[230] Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege,* 54.

Soon, AAA troops began conducting air intelligence work, warning rear areas against attacks, informing pursuit units of enemy aircraft, getting them away from an objective, and using the information about enemy air units and activity to deduce major ground movements.[231] They also gave directions and warning instructions to fighter aircraft.[232]

The overall system also improved by combining field and home intelligence.[233] Desperate units creating intelligence favored a more unified command of aerial forces that included early warning, alert services, and AAA with air intelligence liaisons assigned to sectors.[234] Consolidating all AAA under a single commander, the *Inspektion der Flak im Heimatgebiet* at Frankfurt on 1 September 1916, eventually produced effective results and a lasting reputation. The move to a single commander made AAA units independent of Field Artillery and included control of the Flak Ersatz Battery (reserve units).[235]

Germany realized the importance of having a home defense and effectiveness tied to the creation of a warning and alarm service.[236] Towards the end of 1915, a *Flugmeldedienst* (Aircraft Warning Service) came into being under the FLAK Inspektur. It tied together air intelligence, observation posts, and headquarters to provide early warning of incoming aircraft.[237]

Despite the major consolidation of aircraft under a *Chef des Feldflugwesens (Feldflugchef)*, it still did not maximize efficiency through a streamlined command and control structure, especially in the area of air defense. Senior officers, such as Ernst Wilhelm von Hoeppner, then a Reserve Division commander, saw the need for a single, centralized air

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[231] Hoeppner, *Germany's War in the Air,* 62.
[232] von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 457.
[233] Hoeppner, *Germany's War in the Air,* 63.
[234] Hoeppner, *Germany's War in the Air,* 80.
[235] von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 453.; Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege,* 57.
[236] von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 451.
[237] Neumann and Gurdon, *The German Air Force in the Great War,* 285.; Hoeppner, *Germany's War in the Air,* 32-33, 62.; von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 454.

force.[238] A year later, on March 1916 Von der Lieth-Thomson recommended the need for a single air force under the control of a single commander. He did not define a separate service, only a unified command and control structure.[239] It took the German disaster at Verdun to spur change. On 8 October 1916, von Hoeppner became *Kommandierende General der Luftstreitkraefte* (Commanding General of the Air Force),[240] with a decree from the Emperor, stating "The growing importance of the air war requires that all air combat and air defense resources of the army in the field and in the home, to unite in an office."[241] It provided the unified command of "flyers, air defense, airships, searchlights, and weather service" as suggested in 1914 by Oberst Walter von Eberhardt.[242]

The *Luftstreitkraefte* also assumed responsibility for air-to-ground communications and electronic warfare such as jamming and communications intelligence.[243] Consolidation did not mean independence; the *Luftstreitkraefte* was equivalent to support or service troops and the *Kommandierende General der Luftstreitkraefte* was directly responsible to the Chief of the Army General Staff with Troops (*Chef des Generalstabes des Feldheeres*).[244] "Aircraft engaged in the army co-operation roles of reconnaissance, artillery observation and close support "belonged" to the ground forces being controlled by the fighting

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[238] Hoeppner, *Germany's War in the Air,* 33.
[239] Edward L. Homze, *Arming the Luftwaffe: The Reich Air Ministry and the German Aircraft Industry, 1919-39* (Lincoln: University of Nebraska Press, 1976), 4.
[240] Horst Adalbert Koch, *Flak: Die Geschichte der Deutschen Flakartillerie* (Bad Nauheim: Podzun, 1954), 12-13.; Hoeppner, *Germany's War in the Air,* 78.; Kilduff, *Germany's First Air Force, 1914-1918*, 13.; Imrie, *Pictorial History of the German Army Air Service 1914-1918,* 39.; von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 455.; Deichmann, *USAF Historical Studies: No. 163 German Air Force Operations in Support of the Army*, 6.
[241] Koch, *Flak: Die Geschichte der Deutschen Flakartillerie,* 13.
[242] Koch, *Flak: Die Geschichte der Deutschen Flakartillerie,* 12-13.; Hoeppner, *Germany's War in the Air,* 78.; Kilduff, *Germany's First Air Force, 1914-1918*, 13.; Imrie, *Pictorial History of the German Army Air Service 1914-1918,* 39.; von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 455.
[243] Hooton, *War Over the Trenches*, 113.; Peter Fritzsche, *A Nation of Fliers German Aviation and the Popular Imagination* (Cambridge, Mass: Harvard University Press, 1992), 70.
[244] Deichmann, *USAF Historical Studies: No. 163 German Air Force Operations in Support of the Army,* 6.

commanders."[245] The important factor was the consolidation of air force forces under a single commander that provided commanders a way to maximize the use of limited forces through a single command and control system. Finally, on 1 December 1916, all Home Defense forces fell under the command of the *Luftstreitkraefte*.[246]

Each field Army headquarters and staff was under a Commander of Tactical Support Air Units (Kommandeur der Flieger) with command authority. Air group commanders were attached to corps headquarters in major areas and air liaisons were attached to other corps and division headquarters. Air liaisons (a team of people) at division kept the air officer directing operations informed of the ground situation. They used wired and wireless radios to pass information.[247]

Processes

In 1914, Germany categorized air operations into reconnaissance and observation, attack on infantry or other ground support, air combat, and bombing.[248] By the end of the war these categories still existed but they now viewed air superiority, a lesson learned at the Somme and Verdun, as a pre-requisite for success on the ground and hence the most important air force objective.[249]

Germany quickly learned pursuit aircraft protecting observation and ground strafing aircraft made them more effective,[250] while conversely finding the bomber vulnerable to pursuit aircraft, hence their shift to night bombing.[251] Early in the war, with no technology or method

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[245] Imrie, *Pictorial History of the German Army Air Service 1914-1918,* 48.
[246] Kennett, *The First Air War, 1914-1918*, 88.; Hoeppner, *Germany's War in the Air,* 91.; von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 455.
[247] Deichmann, *USAF Historical Studies: No. 163 German Air Force Operations in Support of the Army, 6,* 130-131.
[248] Neumann and Gurdon, *The German Air Force in the Great War,* 40.
[249] Imrie, *Pictorial History of the German Army Air Service 1914-1918,* 49.; Fritzsche, *A Nation of Fliers German Aviation and the Popular Imagination,* 70-71.; Kennett, *The First Air War, 1914-1918*, 72.
[250] Hoeppner, *Germany's War in the Air,* 83.; Neumann and Gurdon, *The German Air Force in the Great War,* 197.; Georg Paul Neumann, *Die Deutschen Luftstreitkräfte im Weltkriege* (Berlin: E.S. Mittler und Sohn, 1920), 225.
[251] Kennett, *The First Air War, 1914-1918*, 52-53.

to find aircraft in the vastness of the sky, Germany created *Jagdstaffeln (Jastas)* to roam for enemy aircraft to gain air superiority in specific areas.[252]

Command and control processes originated from a need for pursuit aircraft and anti-aircraft artillery to coordinate defensive operations and for air forces to coordinate with ground forces as it had with the British. The first time an aircraft observer directed artillery fire occurred in October 1912 at the artillery school. In 1913, three artillery observers received training with no further progress until the start of the war.[253] Problems communicating from the air soon became evident.

Interaction between air and ground units resulted in the rapid growth of the command and control system. By August 1914, the aircraft had performed so well at the reconnaissance mission it almost replaced cavalry for long-range reconnaissance.[254] Outside of the reconnaissance role, failure to coordinate mirrored the lack of processes between AAA and the alert services. At times Army Headquarters only had intermittent communications with squadrons and airmen essentially fought their own war at first.[255]

Over time and with much trial and error, the Germans established contact patrols called *Infanterieflieger* (Infantry Flyers) to locate friendly troop positions, and *Artillerie-Fliegerabteilungen* (Artillery Flyer Department) for artillery fire direction.[256] These contact aircraft became critical in the command and control node, especially if enemy artillery or bombardment cut telephone lines. If enemy fighters drove away contact aircraft or artillery observation aircraft, then all communications between headquarters and front line troops ended.[257] Contact aircraft were

[252] Fritzsche, *A Nation of Fliers German Aviation and the Popular Imagination,* 70-71.
[253] Hoeppner, *Germany's War in the Air,* 19.
[254] Ibid*,* 16.
[255] Hooton, *War Over the Trenches,* 208-209.
[256] Ibid, 46-47.
[257] Neumann and Gurdon, *The German Air Force in the Great War,* 202.

extremely important in providing commanders with an appraisal of the situation on the ground and the progress of ground fighting. Their formal duties included determining their own infantry line, transmitting tactical reports from the front line to headquarters, and conducting tactical reconnaissance near infantry. Infantry divisions had contact aircraft allocated to them and if escort was required, the divisions made a request through the *Kommandeur der Flieger* (Commander of Aviation Troops).[258]

Flieger Abteilung or *Flieger Abteilung (A)* had *Schutzstaffeln* (Protective Flights) assigned to them to protect contact aircraft. These missions evolved to attacking enemy infantry positions starting on 24 April 1917 with these units known as *Schlachtstaffeln* (Battle Flights). They attacked enemy positions with small bombs, grenades, and machine gun fire. Like contact aircraft, they received their missions from *Armee* headquarters and reported enemy positions and activity to the divisions and the *Gruppenfuehrer der Flieger* via message drop on the way back to the aerodrome.[259] During battle, they remained in contact with headquarters via wireless to adjust to mission requirements.[260]

Early in the war, Army controlled aviation had *Stabs-Offizier der Flieger* (Field Officer) assigned to them, but orders really came through the various ground commanders. A change to the system required requests to come through the *Stabs-Offizier der Flieger*, in essence a liaison officer. The *Stabs-Offizier der Flieger* at the Army level became a

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[258] Germany, *Manual of Position Warfare for all Arms. Part 6, Communication between infantry and aeroplanes or captive balloons* ([London]: General Staff (Intelligence) General Headquarters, 1917), 3.; Neumann and Gurdon, *The German Air Force in the Great War,* 196.; Hooton, *War Over the Trenches*, 123.

[259] Rick Duiven and Dan-San Abbott, *Schlachtflieger!: Germany and the Origins of Air/Ground Support 1916-1918* (Atglen, PA: Schiffer Pub, 2006), 23, 25, 45-46.; Walter Alexander Raleigh and H. A. Jones, *The War in the Air; being the story of the part played in the great war by the Royal Air Force, Vol IV* (Oxford: Clarendon Press, 1934), 436.; Neumann, *Die Deutschen Luftstreitkräfte im Weltkriege*, 43, 134.

[260] Duiven and Abbott, *Schlachtflieger Germany and the Origins of Air/Ground Support 1916-1918,* 44-47.; Raleigh and Jones, *The War in the Air, Vol IV,* 436.

commander called the *Kommandeur der Flieger*. Each *Armee* headquarters had a long-range reconnaissance unit and each corps had a squadron for their work.[261]

Initially, Germany tried to be offensive with its airpower because the defense offered no protection--the vastness of the sky made it easier for the attacker.[262] Without a reliable system to detect and track aircraft, attackers had the advantage. Over time however, Germany assumed a defensive posture to make up for inferior aircraft numbers, using AAA and air warning systems to mass aircraft where needed.[263] They learned the importance of concentration to increase the probability of success.[264] This too was another lesson it relearned defending Germany in the Second World War.

Air defenses on both sides developed a system of transmitting information from the front to headquarters and linking observers to each other and a reporting center by telephone. Initially, observers transmitted target location via Morse Code. The system also extended to the aerodromes. In the rear, friendly troops laid out white arrows to show the direction of enemy flight.[265]

The *Flugmeldedienst* helped inferior German numbers avoid massive Allied fighter sweeps, coming out only to protect their balloons.[266] As with almost everything else regarding the application of airpower, no previous practical experience existed to create a *Flugmeldedienst* for either *Bewegungskrieg* or *Stellungskrieg*.[267] This

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261 Great Britain, *Offence versus Defence in the Air*, 7.; Raleigh and Jones, *The War in the Air, Vol I*, 331.
262 Hoeppner, *Germany's War in the Air,* 87.
263 Kennett, *The First Air War, 1914-1918*, 77.
264 Sykes, *Aviation in Peace and War,* 28.
265 Hooton, *War Over the Trenches*, 44, 46-47. & Neumann and Gurdon, *The German Air Force in the Great War,* 198.
266 Eric Lawson and Jane Lawson, *The First Air Campaign, August 1914-November 1918* (Conshohocken, PA: Combined Books, 1996), 122.
267 Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege,* 55.; von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 458.

system was initially ad hoc with no formal training, [268] developing purely from a frontline need to track enemy fighters.[269] Initially information flowed slowly, but improved once hostile air activity received message priority status over other radio traffic. Creating a unified command by making the AAA commander in an area in charge of both AAA and the alert service solved the problem of the two services not working together.[270] By war's end, Germany had a reputation for having a very efficient AAA service that worked superbly with fighters.[271]

The system used observers passing information to an operations section

> equipped with a communications system which included the guns and searchlights and worked through a central station to the staff officer in charge of anti-aircraft, thence to the pursuit units the balloons, and finally back to the areas to be protected. This word was sent back giving the number of hostile planes, their type, ceiling, direction, and they were followed throughout the course of their flight. The central station decided how far back such data should be sent. This was an important decision and required keen judgement; otherwise there would ensue an unnecessary rousing of troops and civilians, with an upset to the work in the factories, on railroads, etc., which might lead to a falling off in production or war supplies.[272]

Airborne observers also radioed information, gathered visually or through intelligence methods, to Corps group leaders to launch alert aircraft.[273] Aircraft, specifically *Kampf-Einsitzerstaffelln* (Single-seat Fighter Squadrons), received information from the AWS and launched

[268] Hoeppner, *Germany's War in the Air,* 32-33.
[269] Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege,* 55.
[270] Hoeppner, *Germany's War in the Air,* 63-65.
[271] Kennett, *The First Air War, 1914-1918*, 88.; Raleigh and Jones, *The War in the Air, Vol I*, 440.
[272] Hoeppner, *Germany's War in the Air,* 62-64.
[273] Lawson and Lawson, *The First Air Campaign, August 1914-November 1918,* 119.

from a ground alert status to intercept incoming aircraft. The effectiveness of the system forced the enemy to move to more night operations just as the enemy had done to them.[274]

Ground units used 16 X 2 foot cloth panels, lamps, flares, and wireless to communicate and indicate their position when a specially marked aircraft flew over. This prevented infantry from betraying their position to enemy observation.[275] Aircraft communicated with ground units via light pistol, machine gun fire, lamps, wireless, and by dropping reports. Once on the ground, flyers telephoned all reports to ensure the *Armee* headquarters received all information.[276]

Technology

Despite October 1912 being the first time a German observer in an aircraft directed artillery fire, advances in radio technology before the war were small. Aerial observers had no easy way to relay messages.[277] However, the need for a system to communicate information between air and ground units quickly became apparent. Communications initially occurred via pigeons and light signals, but these were not accurate and wireless was not fully explored before the war. The first communication system in place at war's start between artillery and observer aircraft was light signals.[278] Methods included transmitting information from the air to the ground by landing and then debriefing face to face or via telephone, dropping a bag with a message, via panels, lamps, pigeons, and finally by wireless (initially one-way). Generally, Morse Code could easily be tapped out to the ground. Wireless was the quickest method,

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[274] von Eberhardt and Zickerick, *Unsere Luftstreitkräfte, 1914-18*, 454, 456.
[275] Neumann and Gurdon, *The German Air Force in the Great War,* 147, 196.; Hooton, *War over the Trenches*, 123.; Germany, *Manual of Position Warfare for All Arms. Part 6*, 3-5.
[276] Germany, *Manual of Position Warfare for All Arms. Part 6*, 4, 6.
[277] Kennett, *The First Air War, 1914-1918*, 17.; Germany, *Die Militärluftfahrt bis zum Beginn des Weltkrieges 1914*, 20-21.
[278] Hoeppner, *Germany's War in the Air,* 17, 19.

but susceptible to jamming or interception, requiring code to secure the data transmission.[279]

Initially, wireless telegraphy "had been rejected owing to the probable danger to flyers. The war brushed aside this prejudice also, and in December 1914, the first wireless sending sets for airplanes" went to the front and "the first successful cooperation missions were carried out in February 1915"[280]

Early wireless radios were unreliable and easily jammed, but became standard equipment on observation aircraft even though they could only transmit but not receive. [281] The same technological issues affecting the Allies affected Germany. Radios required an unfurled 100-foot trailing antenna, engine noise was too loud to receive, and radio frequencies limited the number of aircraft operating in an area.[282] By April 1917, German aircraft had two-way wireless and no longer had to read ground panels.[283] As a result, ground wireless stations sprang up along the front to gather information from aircraft.[284]

Germany also learned that a command and control system requires redundancy because an enemy could exploit or attack it, intentionally (jamming) or unintentionally (cutting of lines from an artillery barrage). On one occasion a German Giant bomber turned back after realizing it had been discovered via communications intelligence.[285] At first, airborne communications presented unique challenges that limited the speed and information communicated back to the commander

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[279] Neumann and Gurdon, *The German Air Force in the Great War,* 146, 198.; Kennett, *The First Air War, 1914-1918*, 34.; Hooton, *War Over the Trenches,* 75.
[280] Hoeppner, *Germany's War in the Air,* 20.; Neumann and Gurdon, *The German Air Force in the Great War*, 42-43.; Morrow, *German Air Power in World War I*, 72-73.; Kennett, *The First Air War 1914-1918*, 34.
[281] Kennett, *The First Air War 1914-1918*, 34.
[282] Hooton, *War Over the Trenches*, 48.; Kennett, *The First Air War, 1914-1918*, 34.
[283] Hoeppner, *Germany's War in the Air,* 82.; Kennett, *The First Air War, 1914-1918*, 34.; Hooton, *War Over the Trenches*, 145.; Morrow, *German Air Power in World War I*, 72-73.; Kennett, *The First Air War 1914- 1918*, 34.
[284] Neumann and Gurdon, *The German Air Force in the Great War,* 147, 199.
[285] Cole and Cheesman, *The Air Defence of Britain 1914-1918,* 343.

for a decision. Finally, as with the Allies, Germany realized that a warning system was only successful if it permitted the defenders to see the enemy early and far away enough to have time to engage them.[286] As a result, the Germans augmented their observer system with sound locators just as the Allies had.[287]

Mirroring the UK and US, Germany experimented with airpower to see how this new weapon affected war. The rapid evolution of airpower, especially its command and control, was phenomenal. Organizationally, Germany moved towards centralized control by the end of the war. The process followed the same basic concept of gathering data, managing it, and disseminating it. Technologically, Germany had very good radios, sound locators, and the first to have two-way radios for their aircraft. By the end of the war, Germany had a very robust command and control system for air defense and air-to-ground operations.

Section Summary

The period through the end of World War I was a period of remarkable change and growth. While ideas about the command and control of air forces were discussed in peacetime, it was war that drove Armies to address it and make adjustments required to successfully integrate airpower and take advantage of its capabilities. Remarkably, the pattern of change between all three nations, while not identical, is extremely similar. This war led all three nations to conclude almost the same things regarding the command and control of air forces in terms of organization, process, and technology.

Organization

All three nations followed a similar pattern of integrating the airplane into their respective aviation/balloon sections. Both airmen and

[286] Büdingen, *Entwicklung und Einsatz der Deutschen Flakwaffe und des Luftschutzes im Weltkriege,* 55.
[287] Hogg, *Anti-aircraft Artillery,* 37.

traditional soldiers attempted to determine how this new technology could be integrated and what impact it would play in war. Logically, the traditional roles of observation and reconnaissance became the primary missions, although there were glimpses of air-to-ground and air-to-air possibilities.

All three nations placed the aircraft firmly under the control of the Army. A late entrant into the war, the United States Army came with an Air Service, but under Army control despite having a GHQ for some independent action. General Pershing clearly established the Air Service's position upon entry.

For Germany, the Air Service's status changed during the war. It entered the war with airpower completely parceled out to various Army commanders. It took almost a year to create some command and control mechanisms linking flying units to the Corps, Divisions, and almost two years of war for airpower to be consolidated and placed under the control of a single airman. The *Luftstreitkraefte* however remained part of the Army. Army commanders still had control of aircraft assigned to them directly such as observation aircraft. From a command and control perspective, all aspects of air defense fell under a single commander, but this too took almost two years of warfare to occur.

The United Kingdom entered the war with a Royal Flying Corps under Army control, but after more than three years of war, the Royal Air Force came in to existence. While the Corps commanders controlled observation aircraft as in the United States and Germany, the RFC had a much more centralized control of airpower. Ironically, it took the British much longer to centralize airpower for home defense. By the end of the war, the British, like the Germans, came to realize that a structured command and control system for air forces made air defense effective. They learned that air defense was an Air Force responsibility. While the US did not have a home front to protect, they saw the same effect of air defense on the front.

All three nations entered the war with no air-to-ground integration training or process. They all experienced airpower's effectiveness increase for air-to-ground operations when a command and control system existed, able to gather and disseminate information quickly, and linking air and ground units with liaisons. Centralized command and control of air forces added flexibility and the ability to mass aircraft in time and space, increasing airpower's effectiveness and efficiency. The greatest growth to the command and control of air forces came because of air defense needs. This was probably due to the complexity of integrating intelligence, AAA, observers, searchlights, listening devices, and the public outcry for action.

Command and control of air forces also grew extensively during the war for air-to-ground integration. Progress was made in creating processes for integrating air and ground liaisons into the planning process, improving communication between balloons or contact planes and the ground, and using airplanes to support the soldier with direct attacks on the enemy. However, technology, mainly rudimentary wireless technology, made the process relatively static. Training between aircraft and the infantry also hampered the dynamic integration of aircraft. While aircraft could sometimes react to events as they occurred, more often execution followed prearranged agreements separating airmen from soldiers by time or geographical deconfliction. Germany made the most progress integrating aircraft and infantry; probably as a result of their doctrinal heritage of *Bewegungskrieg*.

Process

Remarkably, the processes used by all three nations were similar. While the United States clearly leveraged the British system to build a comparable one able to integrate with the Allies, the Germans were not privy to how the British organized on the front or for Home Defense, yet similar processes developed.

The similarity arises from the very basic needs of a command and control system. A commander must have a method to transmit information, receive information, sort through the information and be able to communicate changes to his forces. It is a continuous process. All belligerents transmitted orders to units via written plans, telephone, and wireless radio. They received information via the same methods, and they all tracked the information at a headquarters, displaying the information visually for a commander to see the "big picture." They all established process for various organizations, such as observers, AAA, Army units, and aircraft squadrons to send and receive information. Finally, all belligerents realized intelligence's criticality to the command and control of air force forces.

Technology

The need to command and control air forces also advanced two technologies; listening devices and wireless radio. All three nations used listening devices. The British did extensive research and development realizing its importance to a command and control system. Advanced warning provided a commander with more decision time. It also allowed a commander to concentrate forces at the place of an attack or redirect forces as necessary. The United States leveraged its Allies' listening devices since they did not have any before entry into the war. The German literature is small regarding listening devices although it is clear from existing sources that such devices were used to enhance the command and control process just as it was on the Allied side.

The growth of command and control of air forces also served as a means to push the advancement of wireless radio. The war clearly highlighted the inadequacies of previous communication methods and the lack of progress made in the area of wireless. The war accelerated the development of wireless radio and proved the only practical solution. Wireless added flexibility and improved the speed with which information flowed. Other lessons included the importance of redundant communications and the importance of the speed and flow of information from commanders to the field and vice versa. Both wired and wireless radio continued to play important parts in the command and control of air forces, with wireless becoming the most important as it was the only way to overcome physical barriers and allow for the real time flow of information to an aircraft operating in a three dimensional world.

Regardless of whether they experienced victory or defeat, the United Kingdom, the United States, and Germany exited the war with the same lessons regarding the command and control of air forces despite the starting point and journey through the war being slightly different.

Chapter 2

The Inter-War Period

Despite exiting WWI with similar lessons regarding the command and control of air forces, the great air powers followed very different paths in subsequent years. Each nation struggled to find a balance between the offensive and defensive capabilities of air power. Offense drove doctrinal development during the period. In this context, the development of command and control systems whether for air-to-air or air-to-ground, evolved slowly until the external environment or non-military actors forced rapid changes.

The UK, as with all other nations demobilized after the war. By the early 1920s however, air defense once again began to attract attention despite the strong focus on an offensive bombardment doctrine. As a result, the UK began an evolutionary journey in the development of its air-to-air command and control system, setting the stage for civilians within the Air Ministry in the 1930s to look at the issue of air defense and command and control holistically. This resulted in dedicated scientific guidance to solve a specific problem. A threatening Germany and the economic environment led to civilian intervention that forced a focus on defensive doctrine. This combination of defensive focus and technological growth led to the creation of Fighter Command's famous command and control system. The UK, however, entered WWII with no air-to-ground command and control system because there was simply no need or desire on the part of both the RAF and Army.

The US also spent the interwar period focus on developing an offensive strategic bombardment theory. Only a few voices within the Air Corps and a push from the Coast Artillery Corps drove the slow evolution of air-to-air command and control doctrine. Technological development (radar) took place due to Coast Artillery Corps requirements rather than Air Corps requirements. Nonetheless, war in Europe spurred the US to speed up the development of its air-to-air command and control system. Its air-to-ground command and control system remained neglected until German performance on the battlefield spurred its development as it would in the UK.

Germany, despite needing an air-to-air command and control system and having one of the most robust air defense systems in the world entered the war with an "eyes and ears" command and control system. Germany did not systematically search for technological solutions to improve detection. Oddly, unlike in the US it did not even pursue radar technology to improve AAA performance. Conversely, an air-to-ground command and control system emerged due to doctrinal and historical reasons. As a result, by 1939, Germany had an air-to-ground command and control system that the UK and the US used as a basis from which to build each of their command and control systems.

The United Kingdom During the Interwar Period

Introduction

The United Kingdom emerged from the Great War economically, militarily, politically, and socially exhausted. Demobilization occurred quickly, but military and civilian leadership began addressing national defense and the new air arm's role in it. The interwar period was characterized by financial problems, interservice rivalry, a diplomatic push for deterrence, and a public fear of bombing. Simultaneously, the RAF did not neglect the development of an air defense command and control system. It remained consistently concerned about defense, explored technological solutions to those problems, and refined processes throughout the period. Political direction finally forced the RAF to focus on defensive operations after years of creating an inflexible and unsustainable offensive doctrine.[1] Overall, by the start of the war, the UK

[1] Malcolm Smith, *British Air Strategy Between the Wars* (Oxford [Oxfordshire]: Clarendon Press, 1984), 270.

was unprepared for air-to-ground operations, but created a capable air defense doctrine anchored on a robust command and control system.

The Political and Economic Situation

The Great War extracted a heavy toll on all nations and demobilization quickly followed. In August 1914, the RAF had approximately 250 officers and 1800 men; it grew to a wartime strength of 30,000 officers and 300,000 men by November 1918. After the Armistice, its strength fell precipitously, to 6000 officers, 52,000 men on 18 October 1919, and 3,280 officers, 25,000 men by 1920.[2]

Post war discussions to discard the RAF and return pieces to the Army and Navy did not occur because it "would be a fatally retrograde step."[3] Attacks on England drove the air service's growth during the war and ensured independence afterwards.[4] Once ideas emerged that the RAF could be responsible for coastal defense, Trenchard argued it required independence to do so. The sinking of a battleship in the US provided him ammunition the admiralty obviously dismissed.[5] Trenchard's fight to ensure the RAF's continued independence coupled with a decrease in the defense budget added to the already bitter rivalry between the RAF and the Army and Navy.[6]

After World War I, neither military nor civilian foresaw a war in the next 10 years and politicians saw little need for the burden of military expenditures. The economic situation did not change until the late 1930s. The Government in power in 1931 ran on an economic platform and did not want to increase military spending, while the financial crisis

[2] Thompson, *The Royal Flying Corps,* 131.; Spaight, *The Beginnings of Organised Air Power,* 211.; Sykes, *Aviation in Peace and War,* 43, 112.; Joubert de la Ferté, *The Third Service,* 69.; J. C. Slessor, "The Development of the Royal Air Force," *Journal of the Royal United Services Institution* Vol LXXVI (May 1931): 324.

[3] Spaight, *The Beginnings of Organised Air Power*, 214-220.

[4] Raleigh and Jones, *The War in the Air, Vol V*, 153.

[5] Scot Robertson, *The Development of RAF Strategic Bombing Doctrine, 1919-1939* (Westport, Conn: Praeger, 1995), 36.

[6] Powers, *Strategy without slide-rule,* 169.

of 1931 affected the entire 1930s.[7] Britain did not however have to contend with pacifist leanings in either the public or government, unlike in the US,[8] although it still had to contend with the post war economic situation and notions that the League of Nations and disarmament were paths to peace.[9]

The deterioration of the international order in the 1930s eventually forced British politicians to react. First, Britain worked through the League of Nations and through various disarmament talks, but the 1931 Japanese invasion of Manchuria and the League's failure to act worried the British. After Germany withdrew from both the League of Nations and the Disarmament Conference in October 1933, the British Government directed the Air Ministry to plan against Germany with France as an ally. In 1935, Germany repudiated The Versailles Treaty, Part 5 and Italy invaded Abyssinia.[10]

The British responded to the growing crisis by increasing aircraft production, labeling the aircraft production plans to counter the threats as "Schemes." The scheme table below shows the 1920s and early 1930s as a period of low aircraft numbers for Home Defense, large growth in bomber aircraft, and the bomber to fighter ratio. Only after the Inskip Report and the new Scheme M does the bomber to fighter ratio drop.

Aircraft Schemes 1923-1939 for the Metropolitan Air Force (Home Defense)						
	52-Squadron Scheme	Scheme A	Scheme C	Scheme F	Scheme L	Scheme M
Start Date	June 1923	July 1934	June 1935	1936	Nov 1938	Nov 1938
Completion Date	12-31-28	12-31-38	31-3-37	31-3-39	3-31-40	1942
Bombers	394	500	840	1022	1352	1360

[7] Smith, *British Air Strategy Between the Wars*, 110.
[8] Colin Sinnott, *The RAF and Aircraft Design, 1923-1939: Air Staff Operational Requirements* (London: Frank Cass, 2001), 5, 60.
[9] Neville Jones, *The Beginnings of Strategic Air Power: A History of the British Bomber Force 1923-39* (London: Cass, 1987), 49.; Smith, *British Air Strategy Between the Wars*, 14.
[10] Sinnott, *The RAF and Aircraft Design, 1923-1939,* 8-9.; Smith, *British Air Strategy Between the Wars*, 149.; Jones, *The Beginnings of Strategic Air Power*, 75.

Fighters	204	336	420	420	608	800
Reconnaissance	--	114	252	294	413	389
Total	598	950	1512	1736	2373	2549
Bomber/Fighter Ratio	1.93	1.49	2	2.43	2.22	1.7

Table: 1[11]

Organization

Thinkers and Theorists

The most notable British theorist during the interwar period was Trenchard. He had a profound and long lasting impact on RAF thinking. Despite being known as a bomber advocate, Trenchard was initially against independent bombing and a strong supporter of ground operations. General Patrick claims Trenchard was against the Independent Air Force, but had it forced upon him by the Air Staff.[12] After the war however, he changed his mind not based on experience, but "because he applied to the peacetime air defence problems his long held erroneous belief that in air warfare all the advantages lay with the attackers."[13] He compared offensive defense with soccer. One does not win playing defense, only by scoring (offense).[14] As Chief of the Air Staff, he was able to push this idea through until accepted without question. He truly believed the counter-offensive to be the best way to defend the nation.[15]

The British developed a version of Douhetian thinking on their own.[16] To Trenchard, paralyzing enemy centers of production and attacking enemy cities is an air force's objective.[17] He did not seem to understand the technical aspects of air operations and assumed success

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[11] Basil Collier, *The Defence of the United Kingdom* (London: Imperial War Museum, 1957).
[12] Patrick, *The United States in the Air*, 22.
[13] Jones, *The Beginnings of Strategic Air Power*, 21.
[14] Andrew Boyle, *Trenchard* (London: Collins, 1962), 520.
[15] Jones, *The Beginnings of Strategic Air Power*, 21, 29.
[16] Sinnott, *The RAF and Aircraft Design, 1923-1939*, 10.
[17] Boyle, *Trenchard*, 576-577.; Robertson, *The Development of RAF Strategic Bombing Doctrine, 1919-1939*, 141.

occurred through the morale and fighting spirit of the bomber crews.[18] Even if bombs did not hit their intended targets, they would have an effect on the population. In 1918, he viewed the effect of morale to material at 20 to 1, but by 1923, the effect decreased to 10 to one.[19] Either way, he believed attacking enemy morale led to victory.[20]

He believed in inter-service cooperation, never stating airpower alone could win wars, and he did not divide airpower into tactical and strategic categories. Air forces attained air superiority first by attacking enemy aerodromes, then attacking the enemy.[21] This concept of air superiority changed over time at the air staff. The idea changed from directly targeting the enemy air force to defeating the enemy military with attacks on airfields and factories in order to attain air superiority. Hence, the bomber became the tool do to so.[22] He also believed bombers could defend themselves and did not require fighter escort.[23]

In conclusion, while British interwar period doctrine appears steeped in Douhetian concepts and while it may seem hard to believe Douhet had no influence on British doctrinal development, the fact remains there is no written evidence of Douhet's ideas within the RAF affecting its doctrinal development as it did the Air Corps Tactical School.[24]

Air Policing

To secure RAF independence and burnish the RAF's relevancy in a fiscally constrained environment, Trenchard argued for air to take over

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[18] Jones, *The Beginnings of Strategic Air Power*, 29.; E. R. Hooten, *Phoenix Triumphant: The Rise and Rise of the Luftwaffe* (London: Arms and Armour, 1994), 89-90.
[19] Jones, *The Beginnings of Strategic Air Power*, 16-17, 29, 42.; Smith, *British Air Strategy Between the Wars*, 61.
[20] Robertson, *The Development of RAF Strategic Bombing Doctrine, 1919-1939*, 141.
[21] Smith, *British Air Strategy Between the Wars*, 56, 58-60, 66.
[22] Smith, *British Air Strategy Between the Wars*, 46, 53, 66, 269, 322.; Sinnott, *The RAF and Aircraft Design, 1923-1939,* 11.; Robertson, *The Development of RAF Strategic Bombing Doctrine, 1919-1939*, 49.
[23] Robertson, *The Development of RAF Strategic Bombing Doctrine, 1919-1939*, 77-78.
[24] Robin Higham, *The Military Intellectuals in Britain, 1918-1939* (New Brunswick, N.J.: Rutgers University Press, 1966) 257-259.

Imperial functions from the Army and Navy under the guise of air control. Air policing paid dividends and helped the RAF survive the Army/Navy and economic onslaught, but added to the rivalry between the RAF and Navy.[25] Air policing was a relatively inexpensive method to secure the empire.

While air control was an official policy,[26] its "requirements did not influence home defense requirements."[27] Nonetheless, home defense units served as a reserve for imperial duty. Despite rejecting "the need to maintain a large strike force on home soil" after WWI[28] and requiring home defense, the Air Ministry and RAF created an offensive doctrine, untested or based on experience. This doctrine, known as counter-offensive, drove RAF planning throughout the 1920s and 1930s until civilian intervention forced the RAF to focus on defense.

Counter-offensive (strategic bombardment)

Almost immediately, after World War I, the Air Staff under Trenchard's guidance formulated the idea the best defense entailed defeating the enemy by counterattacking the enemy in his country. Trenchard supported the counter-offensive as the best course of action[29] possibly as another means to guarantee RAF independence, but it may also have been a natural continuance of British naval policy.

The British Navy's primary mission was home defense, but conducted mostly away from home. A mobile force attacked as well as defended. Jones and Raleigh, in their official history, use an apt analogy: a fencer that always parries will lose if he never attacks. Attack and

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[25] Smith, *British Air Strategy Between the Wars*, 25-27, 33.; Robertson, *The Development of RAF Strategic Bombing Doctrine, 1919-1939*, 31, 53.
[26] Joubert de la Ferté, *The Third Service,* 71.; John Slessor, *The Central Blue; Recollections and Reflections*. (London: Cassel, 1956), 52.
[27] Sinnott, *The RAF and Aircraft Design, 1923-1939,* 7.
[28] Smith, *British Air Strategy Between the Wars*, 31.
[29] Jones, *The Beginnings of Strategic Air Power*, 29.; O'Brien, *Civil Defence*, 18.

parry work together to win. The British extended this concept to aerial warfare as they did for fencing and naval warfare.[30]

In response to the Standing Defence Sub-Committee of the Committee of Imperial Defence, the Air Ministry in March 1922 stated local defense offered some protection, but a general defense did not work and the solution required going on the offensive to attack enemy air bases "to deter or mitigate air attacks on London." This is the beginning of the counter-offensive strategy, in essence the formulation of a deterrent strategy.[31] Counter-offensive strategy revolved around attacking and destroying enemy centers of production and will,[32] based on understanding a nation's industrial systems, similar to the industrial web theory later developed at the ACTS.

The strategy rested on four assumptions: 1) accurate bombing was possible, 2) it would be effective, 3) bombers could defend themselves, and 4) continuous day and night bombing was possible. These assumptions obviously meant a belief, held, and increased throughout the inter-war period, of the bomber's ability to get through despite attacks from fighter aircraft.[33] The bomber's ability to get through resulted from its growing technical superiority over the fighter, lack of demonstrated ability of fighters to intercept aircraft, and preconceived doctrinal paradigms. By 1923, the concept of defending Britain rested on the RAF's ability to carry out independent operations and serve as a deterrent.[34]

Home Defense

"Within two years of the Armistice, nothing was left of them [the home defense structure built in WWI] except a substantial quantity of

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[30] Raleigh and Jones, *The War in the Air, Vol I,* 263.
[31] Robertson, *The development of RAF strategic bombing doctrine, 1919-1939*, 46, 53.; Sinnott, *The RAF and Aircraft Design, 1923-1939,* 3.
[32] Smith, *British Air Strategy Between the Wars*, 269.; Jones, *The Beginnings of Strategic Air Power*, 41.
[33] Sinnott, *The RAF and Aircraft Design, 1923-1939*, 10-13.; Smith, *British Air Strategy Between the Wars*, 70.
[34] Jones, *The Beginnings of Strategic Air Power*, 31.

stored equipment, a small Anti-Aircraft School and the nucleus of an Anti-Aircraft Brigade (later known as the 1st Air Defence Brigade) intended to support an army in the field. By the end of 1920 not a gun or searchlight was deployed for the defence of London, and not one fighter squadron was specifically assigned to home defence." Ashmore's intelligence system disappeared as well.[35] The Air Ministry, placed in charge of air defense in 1918, created the Metropolitan Air Force (the name for Home Defense Squadrons), comprised of 14 bomber and 9 fighter squadrons. The randomly derived bomber-to-fighter ratio reflected British doctrine.[36]

By 1922, Britain, aware airpower neutralized her traditional isolation, realized there were in fact defense requirements—the world was not as peaceful or secure as many had wishfully thought after the Great War. The Balfour Government initiated the Salisbury Committee to address defense. It in turn created the Steel-Bartholomew Committee, headed by Air Commodore J.M. Steel and Col W.B. Bartholomew (from the Air and War Ministry), reporting in April 1923 on the deteriorated state of UK defense. Their report set in motion plans to enhance Home Defense,[37] stating three principles, 1) the air force should be able to receive warning to have time to meet the enemy, 2) ground defenses are essential, and 3) information and intelligence regarding the enemy must be collected and disseminated to all parts of the defensive system.[38]

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[35] Collier, *The Defence of the United Kingdom*, 5-6.; H. W. Hill, Colonel, "Air Defence" *Journal of the Royal United Services Institution* Vol LXXV (February 1930): 109.
[36] Collier, *The Defence of the United Kingdom,* 12.; Derek Wood and Derek D. Dempster. *The Narrow Margin; the Battle of Britain and the Rise of Air Power 1930-40* (New York: McGraw-Hill, 1961), 68.; T. C. G. James and Sebastian Cox, *The Growth of Fighter Command, 1936-1940* (London: Whitehall History Pub. in association with Frank Cass, 2002), 3.
[37] Pile, *Ack-ack,* 51-52.; J. C. Slessor, "The Development of the Royal Air Force," *Journal of the Royal United Services Institution* Vol LXXVI (May 1931): 327.; C. J. Mackay, Flight Lieutenant, "The Influence in the Future of Aircraft Upon Problems of Imperial Defence," *Journal of the Royal United Services Institution* Vol LXVII (May 1922): 286.
[38] Pile, *Ack-ack,* 52-53.; James and Cox, *The Growth of Fighter Command, 1936-1940,* 1-2.

In developing its defensive plans, Britain assumed France to be the enemy. They proposed an organization similar to the one of Ashmore fame comprised of a London or inner AAA and searchlight zone, an aircraft fighting zone of 15 miles in depth broken down into 10 sectors, 15 miles wide with searchlights, and an outer artillery area to break up incoming bomber formations. During night attacks, the system depended only on fighters, as sound locators were ineffective. Finally, the committee recommended the commander of air defenses should have tactical command and administrative control over air and ground units.[39]

By 1923, Britain officially believed "that offensive action by aircraft in the enemy's country is the best form of defense but a defensive system, combined with an active offense, is a necessity."[40] In fact, in 1920, Trenchard argued bombers could defend Great Britain by targeting things at sea and argued for the RAF to be the primary home defense force.[41] Counteroffensive doctrine did not completely smother defensive planning however, as in June 1923 the Salisbury Committee Interim Report stated, "British air must include a Home Defence Air Force of sufficient strength adequately to protect us against air attack by the strongest air force within striking distance of this country."[42]

A joint Air and War Ministry committee, the Romer Committee, named after Major General C.F. Romer examined air defense and tasked "with the devising of a suitable system of command, of measures needed to give warning of approaching raids, and (with the assistance of an expert sub-committee) of communications commensurate with the extent

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[39] Pile, *Ack-ack,* 52-53.; Wood and Dempster, *The Narrow Margin,* 69.; James and Cox, *The Growth of Fighter Command, 1936-1940,* 1-3.; W. T. S. Williams, "Air Exercises, 1927," *Journal of the Royal United Services Institution* Vol LXXII (November 1927): 740.
[40] Sinnott, *The RAF and Aircraft Design, 1923-1939,* 13.
[41] Collier, *The Defence of the United Kingdom,* 10.
[42] Sinnott, *The RAF and Aircraft Design, 1923-1939*, 5, 60.

of the defences now envisaged.” This committee added to the foundation already laid down by the Steel-Bartholomew Committee.[43]

The rebuilding of a new Observer Corps under Ashmore began in 1924 as a direct outcome of the Romer Committee. Ashmore created a system where 20-25 observer posts, located 6-8 miles apart reported via direct lines to one observer center and then in turn to Air Defence Headquarters. The volunteer observers, a part of the constables, become an official part of the RAF in 1929. Coast observer posts were equipped with sound location equipment, while intelligence came from multiple sources; coast guard, ships, wireless transmitter intercept stations. Just as it had during WWI, the need for a central headquarters to control and manage quickly became clear.[44]

Another committee outcome in January 1925 resulted in the creation of Air Defence Great Britain (ADGB) Command at Uxbridge under Officer Commanding-in-Chief, Air Marshal Sir John Salmond. It centralized and directed bomber, fighter, gun, and searchlight operations, but delegated control of everything at the tactical level except “the bomber force to a subordinate command called Fighting Area.” Orders to guns and searchlights passed thorough Army channels.[45] The Command functioned on a dual chain of command with the Air Ministry and War Ministry.[46] A ground officer commanded ground troops for the inner and outer artillery, searchlights, and observer corps, but was collocated with the air commander. The Air Officer Command Fighting

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[43] Collier, *The Defence of the United Kingdom,*16.; James and Cox, *The Growth of Fighter Command, 1936-1940,* 3-4.
[44] James and Cox, *The Growth of Fighter Command, 1936-1940,* 3-4.; Collier, *The Defence of the United Kingdom,* 17, 20.; Wood and Dempster. *The Narrow Margin,* 149.; H. W. Hill, Colonel, “Air Defence” *Journal of the Royal United Services Institution* Vol LXXV (February 1930): 100.; E. B. Ashmore, Major-General, “Anti-Aircraft Defence,” *Journal of the Royal United Services Institution* Vol LXXII (February 1927): 11.; W. T. S. Williams, “Air Exercises, 1927,” *Journal of the Royal United Services Institution* Vol LXXII (November 1927): 740.
[45] Collier, *The Defence of the United Kingdom,* 17.; James and Cox, *The Growth of Fighter Command, 1936-1940,* 6.
[46] Collier, *The Defence of the United Kingdom,* 17.

Area maintained responsibility for control of the 10 aircraft sectors to control defensive operations. Coast Guard stations and naval patrols reported to ADGB. The Thames and Medway coastal defense and the Observer Corps fell under ADGB in 1929. The Home Defense Committee of the Committee for Imperial Defense also solved the issue of multiple intelligence units by making all air defense intelligence go to Fighting Area Headquarters and all other intelligence directly to ADGB.

A communications system built and maintained by the General Post Office linked the various organizations. Information flowed directly to ADGB or Fighting Area Headquarters and then to ADGB.[47] The system provided ADGB a complete air picture on a plotting table, allowing ADGB to initiate action as required.

The Home Defense committee of the Committee of Imperial Defence met again on 22 December 1934 and expanded ADGB into a more continuous air defense system. The system expanded from Portsmouth to London, to include the Manchester district, Sheffield, and Birmingham. The zones increased to a total 26 miles deep based on improved aircraft speed and on the illumination depth required to intercept at night. The Outer Artillery Zone was now 6 miles deep, and included 24 AAA Batteries and 19 searchlights. The Aircraft Fighting Zone (AFZ) increased to 20 miles and included 58 searchlight companies, while the Inner Artillery Zone around London grew to 20 miles, and included 12 AAA batteries, and 6 searchlight companies. As with the earlier system, the outer zone broke up formations and provided illumination for night fighters. The AFZ split into a North and South Fighting Areas and reported to the ADGB commander who was in charge of all air defense operations. The various AAA commanders resided at AFZ headquarters and the General Officer Commanding for the artillery zones and searchlights reported to ADGB Air Officer Commanding (AOC).

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[47] James and Cox, *The Growth of Fighter Command, 1936-1940,* 4-6.

Connectivity between the various pieces of the system remained the same.[48] In 1936, ADGB split to become Bomber Command and Fighter Command along with a newly created Training Command and Coastal Command in 1936, Maintenance Command in 1938 and Reserve Command in 1939.[49]

A shift in British strategy occurred in November 1938 based on Sir Thomas Inskip's recommendation, Minister for the Coordination of Defence. He viewed direct defense as a more effective alternative during the early stages of a conflict and counteroffensive more effective after a successful defense. The concept rested on surviving an initial attack with a strong defensive system then building strength to win the war. He also thought it expensive and ineffective to focus on bombing. Germany had to come to London so the RAF should destroy the enemy in the air before it arrived. This meant a switch from purchasing bombers to purchasing fighters, thus more fighters for the same expenditure.[50]

The Air Ministry balked at Inskip's recommendations, viewing the move as militarily risky done purely for economic reasons. Fighters did not have the same deterrent effect as bombers and could not compete with bombers. It went against the RAF's long established and deep-seated doctrinal ideas. Despite considering direct defense ineffective and an effective counteroffensive as the best defense, the Air Staff had to accept civilian direction.[51] From this time until the start of the war, Fighter Command focused on building a command and control network.

Air-to-Ground Operations

The RAF "firmly rejected the concept of close air support during the interwar period" for doctrinal and policy reasons. The RAF focused on

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[48] Ibid, 11-19.

[49] Smith, *British Air Strategy Between the Wars*, 41.; Colin Latham and Anne Stobbs, *Pioneers of Radar* (Thrup, Stroud, Gloucestershire: Sutton, 1999), 14.

[50] Sinnott, *The RAF and Aircraft Design, 1923-1939,* 9.; Jones, *The Beginnings of Strategic Air Power*, 123-124.; Smith, *British Air Strategy Between the Wars*, 174, 200.

[51] Smith, *British Air Strategy Between the Wars*, 175, 185-186.; Sinnott, *The RAF and Aircraft Design, 1923-1939,* 9-10.; Jones, *The Beginnings of Strategic Air Power*, 123-124.

counterforce and no official policy to commit ground forces to the continent existed.[52] The Army also seemed content to focus on "regimental soldiering."[53] As of mid-1938, no specifically designed aircraft for air-ground attack existed. Army Co-operation aircraft primarily conducted reconnaissance and artillery observation, and only rarely conducted ground attack. Part of the problem was the view that controlling ground attack aircraft once they crossed the line was difficult if not impossible, so communications[54] and procedures remained simple, much as they had been during WWI.

The British understood the difficulty and criticality of communications between air and ground forces, especially regarding maneuver warfare.[55] However, into the late 1920s aircraft still dropped messages, used the same panel system from WWI, and worked with artillery units via one-way wireless.[56]

Despite the little and elementary air-ground communications work before 1927,[57] mobile warfare pushed wireless technology integration[58] following the creation of the Armored Forces in 1927.[59] Communicating with aircraft was difficult and a major issue in developing procedures for ground attack. Nonetheless, the RAF realized ground-attack required

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[52] Ian Gooderson, *Air Power at the Battlefront: Allied Close Air Support in Europe, 1943-45* (London: F. Cass, 1998), 22.; David Ian Hall, *Strategy for Victory: The Development of British Tactical Air Power, 1919-1943* (Westport, Conn: Praeger Security International, 2008), 22.; Sinnott, *The RAF and Aircraft Design, 1923-1939,* 10.

[53] Hall, *Strategy for Victory,* 29.

[54] M. Everett, Colonel, "Fire Support from the Air," *Journal of the Royal United Services Institution* Vol LXXXIII (August 1938) 587, 591.

[55] John A. McDonald, Flight-Lieutenant, "Air Co-operation with the Army," *Journal of the Royal United Services Institution* Vol LXXIV (February 1929): 111.

[56] R. Chenevix Trench, Major, "Signal Communication in War," *Journal of the Royal United Services Institution* Vol LXXII (February 1927): 301.

[57] T. L. Leigh-Mallory, Wing-Commander, "Air Co-Operation with Mechanized Forces," *Journal of the Royal United Services Institution* Vol LXXV (August 1930): 568.; R. Chenevix Trench, Major, "Signal Communication in War," *Journal of the Royal United Services Institution* Vol LXXII (February 1927): 306.

[58] J. C. Slessor, "The Development of the Royal Air Force," *Journal of the Royal United Services Institution* Vol LXXVI (May 1931): 330.

[59] T. L. Leigh-Mallory, Wing-Commander, "Air Co-Operation with Mechanized Forces," *Journal of the Royal United Services Institution* Vol LXXV (August 1930): 568.

special training, communication links, a system of liaisons to interact with the Armored Forces, and an overall system for command and control. In 1930, Wing Commander Trafford Leigh Mallory highlighted the German system of centralized aircraft control used in 1918, allowing their command and control system to react quickly to battlefield events. When the British broke through a line, the Germans moved and concentrated aircraft quickly to stop the advancing British.[60]

In the late 1920s, the RAF created and controlled the two-way radios RAF ground liaisons used to communicate with mobile forces.[61] In 1927, air-to-air radio range was 15 miles and air-to ground radio range was 12 miles. By 1931, radio telephony (R/T) range increased to 40 miles and wireless telegraphy (W/T) to 100 miles.[62] By 1935, reconnaissance aircraft had two-way W/T while artillery aircraft continued to have one-way W/T until 1938.[63]

Field Service Regulation, Volume I, Section 76, addressed the important issue of command. The RAF allocated certain aircraft to the Army under Army command. A RAF commander served as an adviser to the military Commander-in-Chief, with a collocated headquarters, but maintained responsibility for his force. Aircraft allocated to the Army received orders from the Army, while the RAF commander determined employment. Army Co-operation Squadrons detailed to the Corps or Divisions had two flights for counterbattery and one flight for infantry and enemy artillery observation.[64] Intelligence and artillery spotting

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[60] Ibid, 569-571, 576-577.
[61] R. Chenevix Trench, Major, "Signal Communication in War," *Journal of the Royal United Services Institution* Vol LXXII (February 1927): 303.
[62] Hall, *Strategy for Victory,* 23.
[63] Peter Mead, *The Eye in the Air: History of Air Observation and Reconnaissance for the Army, 1785-1945* (London: H.M.S.O., 1983), 148.
[64] Rees Jenkins, "Civil Aspects of Air Defence," *Journal of the Royal United Services Institution* Vol LXXII (August 1927): 565.; A. J. Capel, Group Captain, "Air Co-operation with the Army," *Journal of the Royal United Services Institution* Vol LXXXIV (February 1939): 284.; B. E. Sutton, Squadron Leader, "Some Aspects of the Work of the Royal Air Force with the B.E.F. in 1918," *Journal of the Royal United Services Institution* Vol LXVII (November 1922): 336-337.

exercises between these units occurred annually until 1935 when biannual became the norm.[65]

Despite small steps such as the first RAF *Manual of Army Co-operation (AP 1176)* appearing in 1933, the Army releasing lessons from WWI in 1934, Slessor's book, *Air Power and Armies* being taught at the Staff College,[66] and suggestions by some in the field that joint command should depend on the situation, with mission or preponderance of forces the determining factor,[67] the Air Ministry and War Office simply did not cooperate. Command and control, specifically ground commander control of air forces, was the most contentious issue regarding air-ground cooperation.[68] At the start of World War II, the British remained unprepared for air-ground operations.

Thoughts from the Field

The counterforce doctrine quickly became the leading doctrinal concept. As early as 1922, in the prestigious *Journal of the Royal United Services Institute* (RUSI), writers preached the virtues of the offensive. One typical statement comes from Flight Lieutenant C. J. Mackay, declaring,

> in the air there must only be one policy—a ruthless offensive directed against (a) enemy aerodromes, (b) enemy aircraft over enemy territory, (c) political, military and naval objectives in enemy territory. When (a) and (b) have achieved air supremacy, the enemy will be compelled to employ the bulk of his air resources in local defense at the dictation of public opinion, which is a force that things not in terms of the ultimate objective, or of strategy,

[65] John A. McDonald, Flight-Lieutenant, "Air Co-operation with the Army," *Journal of the Royal United Services Institution* Vol LXXIV (February 1929): 110.; Mead, *The Eye in the Air,* 149.
[66] Hall, *Strategy for Victory,* 28-29.
[67] H. Rowan Robinson, Brigadier-General, "The Role of Aircraft in Coast Defence," *Journal of the Royal United Services Institution* Vol LXXV (August 1930): 488.
[68] Hall, *Strategy for Victory,* 25, 40.

> but in terms of its own immediate safety, and it is that way that defeat lies…[69]

while Group Captain W. F. MacNeece stated, "needless to say, it is most fully recognized that the offensive handling of our defensive measures is in the highest degree essential."[70]

At the conclusion of his 1928 RUSI lecture entitled "Air Power and its Application," MacNeece, Air Ministry member, summarized the prevailing thought of the time, "The passive defence of this country by air is at best only a palliative. The inevitable trend in scientific development of air equipment will place the attackers in an ever increasingly stronger position vis-à-vis the defense."[71] These thoughts prevailed so much that in 1931 the British Air Staff specified a bomber with the same performance as a fighter, but with a 600-mile range and a 1000-pound bomb load. If technically possible, then the defense required examination.[72]

Despite the heavy emphasis on offensive operations, the Air Staff did not neglect home defense, spending time dealing with the problem of fighting an unseen enemy.[73] Defense did have advocates, such as Ashmore who believed Great Britain spent the 1920s "relying too much on the defensive power of offensive bombing" despite bombing having never been known or proven to stop or deter raids. However, evidence existed that a strong defense caused 14% loss rates to the Germans in 1918, forcing them to stop the London raids. While defense of Great

[69] C. J. Mackay, Flight Lieutenant, "The Influence in the Future of Aircraft Upon Problems of Imperial Defence," *Journal of the Royal United Services Institution* Vol LXVII (May 1922): 290.
[70] W. F. MacNeece, Group-Captain, "Certain Aspects of Air Defence," *Journal of the Royal United Services Institution* Vol LXXI (February 1926): 100.
[71] W. F. MacNeece Foster, Group Captain, "Air Power and Its Application," *Journal of the Royal United Services Institution* Vol LXXIII (May 1928): 258.
[72] Sinnott, *The RAF and Aircraft Design, 1923-1939,* 137.
[73] W. F. MacNeece Foster, Group Captain, "Air Power and Its Application," *Journal of the Royal United Services Institution* Vol LXXIII (May 1928): 255.

Britain was not perfect in 1918, it was sufficient to stop attacks,[74] thus effective. Both Great Britain and the US found raids without effectively defeating enemy defenses highly prohibitive in WWII.

Others, such as Brigadier General Rowan Robinson, in discussing coast and harbor defense, concluded likewise, stating, "the new arm appears to be of equal value to either side, perhaps favoring the defense slightly."[75] Squadron Leader J. O. Andrews openly countered the overemphasis on offensive ideas. In November 1931, he discussed the dangers of relying on a doctrine based completely in theory, in which no real world application and imperfect exercises clouded the issue. He addressed whether "a defensive policy may be desirable, but also whether the general opinion that it would be ineffective is justified." Keenly aware the major problem with defense was interception, he emphasized good intelligence, communication, and the early detection of aircraft, highlighting the improvements in the observation and communications since 1918.[76] Aware of the changes in warfare since 1918 he stated,

> technical progress has rendered our limited war experience of interception largely valueless. Because the offensive is so addictive as a general principle, there is a real danger that the strategist may be led into an unreasonable opposition to a defensive role for aircraft, overlooking the fact that it has not yet been conclusively shown to be undesirable or impractical. A policy in the main defensive may in certain circumstances be more prudent and profitable than an air Plan XVII.[77]

The offensive was so firmly entrenched as a doctrinal concept that the only response to German rearmament by Chief of the Air Staff, Sir

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[74] H. W. Hill, Colonel, "Air Defence" *Journal of the Royal United Services Institution* Vol LXXV (February 1930): 111, 114.
[75] H. Rowan Robinson, Brigadier-General, "The Role of Aircraft in Coast Defence," *Journal of the Royal United Services Institution* Vol LXXV (August 1930): 479.
[76] J. O. Andrews, Squadron Leader, "The Strategic Role of Air Forces," *Journal of the Royal United Services Institution* Vol LXXVI (November 1931): 740-742.
[77] Ibid, 743. Plan XVII was the disastrous French strategy for taking the offensive in 1914.

Edward Ellington in 1934 was the suggestion that the only way to defend the UK from Germany entailed building a power bomber force.[78] Bombardment adherents truly believed "modern systems of air defense, such as those being built up in Europe today, rely, firstly on offensive operations,"[79] and "that strategical bombing, in so far as it has been tried in actual warfare, has proved a success,"[80] and therefore they planned on bombers fighting their way in and out.[81] Even politicians clung to the idea the bomber would get through.[82]

The defensive power of bombers reinforced the view that defensive fighters would not have to engage enemy fighters, thus no need for fighter escorts. The fear that existing single-seat fighters would be ineffective against bombers led to the development of heavily armed, less maneuverable fighters. The symbols of this policy were the Boulton-Paul Defiant and Bristol Blenheim.[83] Slessor simply thought they were too optimistic about bombers' ability to bomb without escorts, stating,[84]

> Before the days of the eight-gun monoplane and—more particularly—of radar early warning, the lethality of the fighter had yet to be proved, the possibility of adequate early warning was so remote, the numbers required to give a reasonable interception rate by any system of standing patrols so prohibitively large, that perhaps we may be excused for laying what we now know was too much stress on the importance of a bomber counter-offensive as the major element of defense.[85]

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[78] Jones, *The Beginnings of Strategic Air Power*, 77.
[79] R. A. Cochrane, Wing Commander, "The Effects of the Development of Air Power on British Interests in the Mediterranean," *Journal of the Royal United Services Institution* Vol LXXXI (May 1936): 248.
[80] Oliver Stewart, Major, "The Doctrine of Strategical Bombing," *Journal of the Royal United Services Institution* Vol LXXXI (February 1936): 101.
[81] Jones, *The Beginnings of Strategic Air Power*, 138.
[82] Charles A. Selden By Cable to THE NEW YORK TIMES, "Simon Urges Europe to Ban Use of Force: British Foreign Secretary Says ..." *New York Times (1923-Current file);* Nov 11, 1932; ProQuest Historical Newspapers: The New York Times (1851-2009) pg. 4
[83] Author discussion with Dr. Richard Muller, 25 February 2014.
[84] Slessor, *The Central Blue,* 205.
[85] Ibid, 167.

The advent of radar and the Fighter Command system did not really change British theory. There simply was no practical application to test the validity or shatter the existing paradigm.[86] Even with radar, the advantage it gave fighters remained unclear to the Air Staff. They continued to believe in the bomber's supremacy over the fighter despite a growing chorus of opposing views stating the advances in fighter design were beginning to provide it an advantage over bombers.[87]

Bomber Command however began to have second thoughts. In 1937, its Commander-in-Chief John Miles Steel, asked the Air Staff to rethink the policy of no fighter escort as he did not think they would be able to survive attacking Germany without them.[88] His successor, Sir Edgar Ludlow-Hewitt, "feared that his bombers would be helpless against fighters which had sufficient armour to make them invulnerable to machine-gun fire when attacking bombers from astern"[89] and by the Czech Crisis, even he believed the best hope lay in a defensive plan.[90]

Ludlow-Hewitt, in 1938 and 1939 formally reiterated the need for fighter escort and Bomber Command's low readiness rate. The Air Staff rejected the request, condemning his defeatist attitude.[91] After all, in May 1939, an Air Ministry assessment on fighter production stated, "Generally speaking they are all intended for Home Defence i.e. the destruction of enemy bomber aircraft in circumstances in which they are unlikely to meet enemy fighter aircraft."[92]

Events Around the World

The Spanish Civil War provided nations an insight into the performance of various aircraft and highlighted that the fighter had

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86 Smith, *British Air Strategy Between the Wars*, 70.
87 Sinnott, *The RAF and Aircraft Design, 1923-1939*, 179.
88 Jones, *The Beginnings of Strategic Air Power*, 130.
89 Sinnott, *The RAF and Aircraft Design, 1923-1939,* 179.
90 Jones, *The Beginnings of Strategic Air Power*, 143.
91 Ibid, 149.
92 Sinnott, *The RAF and Aircraft Design, 1923-1939*, 181.

clearly advanced technologically versus the bomber.[93] French Spanish Civil War observer Capitaine Didier Poulain stated, “So far as the conduct of air warfare itself is concerned, it is now definitely admitted that the bomber is practically without defence against the fighter,” specifically the single seat fighter. The loss of fighter escort meant heavy bomber losses. As a result, the bomber’s vulnerability to the fighter, forced both sides to night bombing.[94]

The war also highlighted the effectiveness of assault aircraft against ground troops[95] and the effectiveness dive-bombing with air superiority attained and no enemy AAA.[96] This and especially the 1937 bombing of Guernica, added to the British public’s fears of airpower’s potential.[97]

Thoughts about command and control also began to evolve during the interwar period. The French preface to Ashmore’s *Air Defense*, written by Marechel Petain, *Inspecteur General de la Defense Aerieme du Territoire* emphasized not only the importance of attacking an enemy air force at its bases, but also the importance of having a defensive plan, including fighters. The most important part of any defensive system, however, is the information service. Information and its use by fighters can only be effective within a well-established command and control system.[98] The Spanish Civil War demonstrated how even a primitive command and control system of airborne aircraft using observer

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[93] Ibid, 9.
[94] Didier Poulain, Capitaine, “The Role of Aircraft in the Spanish Civil War,” *Journal of the Royal United Services Institution* Vol LXXXIII (August 1938): 582-584.
[95] Ibid, 586.
[96] F. Jebens, Major, “Fire Support From The Air,” *Journal of the Royal United Services Institution* Vol LXXXIV (February 1939): 75.
[97] Slessor, *The Central Blue*, 150.
[98] Marechal Petain, “Air Defense,” *Journal of the Royal United Services Institution* Vol LXXVIII (August 1933): 541.

information and passing enemy direction via ground panels to airborne defensive fighters could be effective.[99]

On the technological front, while the Italians did not fight against another modern Air Force, wireless proved itself critical in maintaining continuous contact between aircraft and ground forces for passing reconnaissance information and coordinating attacks against various tribes during their colonial operations in North Africa.[100]

Exercises and Maneuvers

Exercises and maneuvers were excellent venues to test and improve tactics and technology, train, and conduct joint operations, but they also tended to reinforce strongly held concepts and beliefs. Exercises conducted between the wars demonstrated the growth of command and control concepts.

With war weariness residing and the Steel-Bartholomew Committee recommendations, early warning exercises began over the Channel in 1923.[101] The 1926 exercise, while not realistic, clearly demonstrated the need for aircraft location technology.[102] Other large air defense exercises followed, concluding to varying degrees that intercepted bombers would suffer prohibitive losses.[103]

The first major air defense exercise occurred in July 1927. The inability to detect aircraft was once again evident as clouds helped bombers get to their target unscathed. Other parts of the defense proved efficient however, especially the Observer Corps. The exercise reemphasized the need for early and accurate information and the need to differentiate between friend and foe—concepts critical to an effective command and control system. Bomber success highlighted the difficulty

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[99] Didier Poulain, Capitaine, "The Role of Aircraft in the Spanish Civil War," *Journal of the Royal United Services Institution* Vol LXXXIII (August 1938): 583-584.
[100] "Operations of the Italian Air Force in North Africa, 1929-31," *Journal of the Royal United Services Institution* Vol LXXVIII (May 1933): 377.
[101] Wallace, *R.A.F. Biggin Hill*, 73.
[102] Pile, *Ack-ack,* 55.
[103] Sinnott, *The RAF and Aircraft Design, 1923-1939*, 69.

of air defense, added to the belief the bomber would get through, and sowed the seeds for a belief in night bombing's effectiveness despite the inability to find targets at night or through clouds.[104]

Air defenses performed better during the 1928 exercise, with only 9 of 57 bomber raids evading the defense. Ten years prior, during May to July 1917, 52 German bombers attacked London and only 3 defenders could attack them of the 74 to 95 aircraft available daily. Night tracking, searchlight use, and the concepts of concentrating defensive aircraft all proved more effective.[105]

The objectives for the 1930 exercise included long distance bombing and strategic defense. Blue used constant airborne patrols for defense and attacked enemy targets, but attacked aerodromes only toward the end. Red conducted reconnaissance of Blue aerodromes early and focused on intercepting wireless communications to locate enemy aircraft while concentrating all attacks on Blue aerodromes. Red focused their small number of searchlights and wireless radios for defense south of the capital and found their defense only worked against slow bombers, not faster ones due to the time needed to conduct an intercept. They also used bombers near enemy aerodromes to track and shadow aircraft, sending the information via wireless to Red interceptors. Finally, they placed tracker aircraft 40 miles from the capital to track incoming aircraft, but this proved unsuccessful. While the exercise highlighted the importance of early information, wireless, and the need for observation posts, it was the offensive against blue aerodromes that reinforced the counterforce doctrine.[106]

[104] Jones, *The Beginnings of Strategic Air Power,* 66.; W. T. S. Williams, "Air Exercises, 1927," *Journal of the Royal United Services Institution* Vol LXXII (November 1927): 744.
[105] H. W. Hill, Colonel, "Air Defence" *Journal of the Royal United Services Institution* Vol LXXV (February 1930): 110-111, 115.
[106] W. M. Yool, Flight Lieutenant, "Air Exercises 1930," *Journal of the Royal United Services Institution* Vol LXXV (November 1930): 755-762.

During the 1931 exercise, 40 percent of intercepts failed at night and 25 percent during the day. This once again reinforced the perception of the ineffectiveness of the defense.[107] Both bombers and defending fighters suffered substantial damage leading a 1931 *RUSI* article author to state no prudent person relies only on defense or counter force and while no defense is perfect, it must inflict casualties to deter further bombing. He concluded the only way to defend is to have an intelligence and information gathering system.[108]

The 1932 air defense exercise worked on detection methods, to include using intelligence, observation from ships, and ground observers. Once again, the Observer Corps proved very effective and accurate,[109] while acoustic sound locators failed to provide reliable data.[110] To deal with fighter versus bomber speed differentials, fighters, now fitted with radios[111] to receive airborne updates, had more space to conduct an intercept. The exercise reinforced the concept that interception required good information. The overall conclusion: enough successful intercepts occurred to make continuous raids prohibitive, even if some bombers got through. This confirmed what Ashmore learned in WWI—the system does not need to be perfect, just good enough.[112]

During the 1933 exercise, only 16 of 47 day raiders and only 23 of 79 night raiders made it in and out of the target area.[113] While sound mirrors detected all the raids sent towards them, most detection took place at less than 10 miles—hardly soon enough to assist with

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[107] Jones, *The Beginnings of Strategic Air Power*, 66-67.; Sinnott, *The RAF and Aircraft Design, 1923-1939*, 71.

[108] C. C. Turner, Major, "British and Foreign Air Exercises of 1931," *Journal of the Royal United Services Institution* Vol LXXVI (November 1931): 733-735, 739.

[109] F. A. De V. Robertson, Major, "Air Exercises, 1932," *Journal of the Royal United Services Institution* Vol LXXVII (November 1932): 809, 812.

[110] Zimmerman, "Tucker's Acoustical Mirrors: Aircraft Detection Before Radar," 92.

[111] Sinnott, *The RAF and Aircraft Design, 1923-1939,* 70.

[112] F. A. De V. Robertson, Major, "Air Exercises, 1932," *Journal of the Royal United Services Institution* Vol LXXVII (November 1932): 810-814.

[113] "Cyclops," "The Air Defence of Great Britain Command Exercise, 1933," *Journal of the Royal United Services Institution* Vol LXXVIII (November 1933): 745.

intercepts.[114] During the exercise, bombers flew scripted routes, used their lights to simulate searchlight hits, AAA firing, and announced their position to simulate observation by the Observer Corps. Despite these artificialities, the exercise demonstrated that raiders could be intercepted given timely information.[115]

The 1935 exercise once again demonstrated the difficulty, but potential for an effective home defense if given accurate enemy positions.[116] Despite accurate information from a 200-foot sound mirror detecting 3 out of 4 raids at 18 miles and the 4th at 10 miles, fighters had difficulty intercepting incoming bombers.[117] Even with known routes, defending fighters only intercepted 2 of 5 bombers. The exercise also highlighted the need for information to flow faster.[118] Finally, the exercise emphasized the need for a system to absorb, analyze, and react to the data. As a result, a central plotting tool was "built to assess all data received by the mirrors and transmit the computed location of aircraft to ADGB Headquarters."[119]

By 1937, exercises had demonstrated the difficulty of accurate bombing. Increased aircraft speed meant a smaller bomb window, requiring more training and higher crew efficiency.[120] Technologically, erratic and inaccurate radar data meant creating processes that flowed data to the sector operations room and highlighted the need for filter rooms.[121] Overall, the control net and radar worked, but fighter

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[114] Zimmerman, "Tucker's Acoustical Mirrors: Aircraft Detection Before Radar," 93.
[115] "Cyclops," "The Air Defence of Great Britain Command Exercise, 1933," 739, 741-742.
[116] Ronald William Clark, *Tizard* (Cambridge: M.I.T. Press, 1965), 106.; A. Claud Wright, Group Captain, "Air Exercises, 1935," *Journal of the Royal United Services Institution* Vol LXXX (November 1935): 832.
[117] Zimmerman, "Tucker's Acoustical Mirrors: Aircraft Detection Before Radar," 94, 96.
[118] Wood and Dempster, *The Narrow Margin,* 126.; Latham and Stobbs, *Pioneers of Radar,* 8.
[119] Zimmerman, "Tucker's Acoustical Mirrors: Aircraft Detection Before Radar," 94-95.
[120] Jones, *The Beginnings of Strategic Air Power*, 134.
[121] Jack Gough, *Watching the Skies: A History of Ground Radar for the Air Defence of the United Kingdom by the Royal Air Force from 1946 to 1975* (London: HMSO, 1993), 5.

capability was still unable to compete against the bombers to catch and intercept them.[122]

The 1938 exercises demonstrated the improvement in radar capability, but demonstrated its poor performance against low level flying aircraft, leading to the development of Chain Home Low (CHL) radars.[123] The August 1938 exercise demonstrated not only that the command and control system worked, but also how it could be easily overwhelmed. Additional lessons led to the creation of Identification Friend or Foe (IFF) and improvements to the filtering process. The arrival of the Hurricane fighter also improved the defense. Command and control continued to improve throughout 1939, and in August 1939, several firsts occurred: joined radar and observer plots, radar information given to observers, and IFF all made their appearance.[124] The pieces came together at the last moment and although the British had created an effective command and control system, they continued to refine it throughout the war.

Planning For War

During the interwar period, the UK created several war plans. These plans, called Western Air Plans 1-13, covered a wide range of operations. Western Air Plan No 1 (WA1) called for attacking Luftwaffe supply, organization, and infrastructure to blunt an attack and thereby assist Fighter Command. It was "designed only to reduce the German air offensive to a scale which the fighters and ground defense could control." The Air Staff did not view this plan as an effective use of Bomber Command or the counterforce strategy they had so diligently developed and cherished. WA5, the plan to attack German industrial facilities, was the only plan in which bombers operated in an independent role, but only after the initial attack finished and fighters had defended the UK.[125]

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[122] Wood and Dempster, *The Narrow Margin,* 78.
[123] Latham and Stobbs, *Pioneers of Radar,* 20.
[124] Wood and Dempster, *The Narrow Margin,* 78, 139-142, 144.; Gough, *Watching the Skies,* 6.
[125] Jones, *The Beginnings of Strategic Air Power*, 127, 131.; Smith, *British Air Strategy Between the Wars*, 287, 291.

WA4 dealt with attacking railways and bridges, while WA6, the Oil Plan, specifically focused on attacking German oil production and storage. WA5 and WA6 were the most popular as the Air Staff thought them the most decisive.[126]

Processes

The British learned the importance of a well-organized command and control system for home defense during WWI. The command and control processes used in WWI carried forward through the interwar period and into WWII almost intact, albeit with the addition of newer technology. Sometimes it was a matter of overlying new technology on an old method, rediscovering a method, and adapting it to the new situation, or a perfection of a well-established process. Sir Henry Tizard served as Rector of Imperial College in London, and head of the Committee for the Scientific Survey of Air Defence, better known as the Tizard Committee. Tizard knew information was useless without an organization to do something with it and suggested developing intercept techniques even before radar became operational. On 13 July 1936, Tizard presented to the Air Ministry a test called "The Biggin Hill Experiment" to determine 1) percentage of intercept success, and 2) how close fighters could get to the bombers. In August 1936, Tizard met with RAF officers and instructed them to develop procedures to intercept enemy aircraft if given detailed information such as bearing, distance, and altitude. They subsequently developed the procedures, including the communications between controller and pilot.[127]

The officers tried many things, processes, and equipment, but in the end, a simple solution existed: The Principle of Equal Angles. A fighter and bomber are each two sides of an isosceles triangle with a base between the two. To keep a fighter on target to the bomber meant

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[126] Smith, *British Air Strategy Between the Wars*, 295-296, 300.

[127] Wallace, *R.A.F. Biggin Hill*, 92-93.; Gough, *Watching the Skies,* 4-5.; Clark, *Tizard,* 150.; E. G. Bowen, *Radar Days* (Bristol, England: A. Hilger, 1987), 30.; Latham and Stobbs, *Pioneers of Radar,* 12.

keeping the angles equal on the base. A controller could quickly adjust and even conduct the intercept by "eye." The first 100 tests with real aircraft achieved a 93% success rate.[128] By February 1937, a control school opened to begin training the large number of controllers needed to operate the envisioned Chain Home system.[129]

Before the availability of reliable radars, Biggin Hill used HF Direction Finding (DF), known as "Pipsqueak" to track friendly fighters and practice the new intercept techniques. By early 1937, DF equipped fighters, accurate bomber location to within two miles, and regular updates made an intercept more likely. They also developed code words to reduce the danger of communication interception and hamper the enemy's ability to utilize the data transmitted over a clear frequency.[130] By the end of the year, all sectors conducted intercepts with the new system and aircraft controlled from Biggin Hill had secretly intercepted airliners and other aircraft flying as low as 6000 to 9000 feet and in ten-tenths clouds.[131]

The arrival of radar required an overhaul of the command and control system. A sector station, such as Biggin Hill, contained an operations room into which information flowed from Group Headquarters, radar stations, and the Observer Corps. A new vertical plexiglass screen with writing on the reverse side gave a controller the best view of tracks and allowed the controller to handle multiple intercepts.[132]

Filter rooms originated to sort out and correlate data (radar or observer) coming into a center. The filter room or center had a plotting table onto which plotters placed observer information. Three different

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[128] Wallace, *R.A.F. Biggin Hill*, 93.; Clark, *Tizard* 151-152.
[129] Wood and Dempster, *The Narrow Margin,* 134.; Clark, *Tizard,* 154.
[130] Joubert de la Ferté, *The Third Service,* 127.; Clark, *Tizard,* 155.; Latham and Stobbs, *Pioneers of Radar,* 13.; Colin Latham and Anne Stobbs, *Radar: A Wartime Miracle*. (Phoenix Mill: Sutton Pub. 1996), 71.; Gough, *Watching the Skies,* 4-5.
[131] Wallace, *R.A.F. Biggin Hill*, 94.
[132] Wallace, *R.A.F. Biggin Hill*, 94; Clark, *Tizard,* 154.

colored counters, red for 5 minutes, yellow for 10 minutes, and blue for 15 minutes, indicated the minutes from the report. One person tracked historical information and another teller told the information back to headquarters. The entire process took only 30 seconds from observer to headquarters.[133] Filter rooms evolved to evaluate overlapping radar data and provide the most accurate data to the General Situation Map (GSM) at Fighter Command for the Air Officer Commanding. Information on the GSM then filtered back down to the controllers with the most accurate information.[134]

By the time the Battle of Britain began, Fighter Command had created a command and control system without which it would not have won the battle. The process was brilliantly simple, but remarkable for the time. The system provided almost real-time information to everyone connected. For everyone, "from commander-in-chief down to sector controller the display of information was the same and changes were made simultaneously throughout." Standardized operations rooms existed from headquarters down to each individual sector.[135]

Communication lines, the backbone to the system riding on commercial lines, were only partially complete by the time of the Munich Crisis. Eventually, a separate military network called the Defence Teleprinter Network (DTN) arose to handle the heavy traffic and provide redundancy.[136]

Fighter Command's operations room, originally located at Uxbridge, moved to Bentley Priory in 1936 and was the only operations room to receive all radar feeds from across the country. Each radar station had its own filter officer to plot the incoming data on the plotting

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[133] E. B. Ashmore, Major-General, "Anti-Aircraft Defence," *Journal of the Royal United Services Institution* Vol LXXII (February 1927): 12.
[134] Latham and Stobbs, *Pioneers of Radar,* 13.; Latham and Stobbs, *Radar: A Wartime Miracle,* 24.; Gough, *Watching the Skies,* 8.
[135] Wood and Dempster, *The Narrow Margin,* 171.
[136] Ibid*,* 172.

table. The filter officer crosschecked the incoming radar data with IFF, D/F data, and Observer Corps information flowing in from the subordinate Fighter Groups. Raid track data remained on the plotting board while intercept data was transferred to a "Totalizer" board. Critical personnel such as the Antiaircraft Artillery Commander, Royal Observer Corps Commander, Bomber and Coastal Command liaisons, Admiralty liaisons and Ministry of Home Security liaisons all resided at Fighter Command Headquarters to provide input into the system or send information out. The command and control system was not RAF only; it required inputs from and outputs to multiple organizations to be successful.[137]

Fighter Command had subordinate Fighter Groups, each responsible for a number of sectors, except for 60 Group which had responsibility for all radar stations in the UK. Each sector had a main fighter base, headquarters with standard operations room, D/F equipment, and of course other airfields. Each Fighter Group had subordinate units, known as Sectors A-Y. Controlling occurred from these sectors' operations room. An Operations "A" and an Operations "B" assisted the main controller. The Operations "A" received information from Group headquarters and the Operations "B" operated the communications, while two deputy controllers used the D/F, or "Pip-squeak" information to calculate the intercepts. Finally, a local gun control officer and Observer Corps liaison were also present.[138]

Groups	Headquarters	Area
9 Group	Preston	N.W. England
10 Group	Rodlow	S.W. England

[137] Ibid, 173-175.
[138] Wood and Dempster, *The Narrow Margin,* 173-177.; Report. Air Defence of Great Britain Intelligence Memorandum No. 2, Notes on the G.A.F. Day Fighter System in Western Europe, 18 February 1944, Call # 512.662, p. 1, in the USAF Collection, AFHRA, Maxwell AFB, AL.

11 Group	Uxbridge	S.E. England
12 Group	Hucknall	E. and C. England
13 Group	New Castle	N.E. England and Part of Scotland
14 Group	Inverness	Scotland
82 Group	Stovmont	Ireland
60 Group		N/A

Table: 2[139]

Technology

The interwar period witnessed the astronomical growth in technology, specifically radar, which proved to be the greatest contributor to saving Britain. From the beginning, government support for early warning research was critical in the drive to find a way to provide early warning of incoming enemy aircraft.[140]

Listening Devices

After WWI, the British searched for replacements to the acoustic machines used in the war under the Acoustical Section of the Signals Experimental Establishment (later renamed the Air Defense Experimental Establishment in 1925). Small-scale efforts at heat detection also occurred, although these efforts focused on large concrete circular mirrors and directional microphones at the mirror's focus. These provided about a 10-mile detection range, amounting to approximately five extra minutes for an intercept in the 1920s, but increasing aircraft speed made acoustic methods less than an ideal solution.[141]

Overall, experiments with small sound mirrors proved ineffective with the longest detection at 18 miles. The most ambitious project was a chain of 20-foot sound mirrors along the southern coast with only two

[139] Report. Air Defence of Great Britain Intelligence Memorandum No. 2, Notes on the G.A.F. Day Fighter System in Western Europe, 18 February 1944, Call # 512.662, p. 1, in the USAF Collection, AFHRA, Maxwell AFB, AL.
[140] Jones, *The Beginnings of Strategic Air Power*, 87-88.
[141] Wallace, *R.A.F. Biggin Hill*, 72-73, 91.; Collier, *The Defence of the United Kingdom,* 22.; Zimmerman, "Tucker's Acoustical Mirrors: Aircraft Detection Before Radar," 78.

built. By 1929, a 30-foot device with the same range as 20-foot mirrors arrived, but with better accuracy in elevation. By 1930, a massive 200-foot mirror detected an aircraft at 30 miles, and participated in exercises until 1935. The Air Ministry cancelled a proposal to build one at the Thames estuary due to the progress with radar. By 1938, all long-range acoustic research ceased.[142]

Radar

By the mid 1930s, with an increasingly threatening Germany, a growing bomber to fighter capability gap, and the results of the 1934 exercises indicating, "the bomber will always get through," Dr. A. P. Rowe, a scientist from the Air Ministry Director of Science Research, conducted a thorough investigation of air defense. From records at the Air Ministry, he discovered a lack of air defense capability and a lack of effort on the part of the Air Ministry toward solving the air-warning problem. Dr. Rowe submitted his report to his superior, Dr. Harry Wimperis, with the claim that unless Great Britain solved the air-warning problem, it would lose the next war. He recommended action to rectify the situation. Wimperis took the recommendation, prepared a report outlining the issues, including the state of the technology (especially radio technology), and recommended a committee of scientist attempt a concentrated scientific solution to the problem.[143]

The Air Ministry reacted positively to Wimperis' 12 November 1934 report, creating the Committee for the Scientific Survey of Air Defence, or the Tizard Committee in December 1934, to solve the air defense problem. It was "to consider how far recent advances in scientific and

[142] Ian White, *The History of the Air Intercept (AI) radar and the British Night-fighter 1935-1959* (Barnsley: Pen & Sword Aviation, 2007), 2.; Collier, *The Defence of the United Kingdom,* 22.; Zimmerman, "Tucker's Acoustical Mirrors: Aircraft Detection Before Radar," 78, 97.

[143] White, *The History of the Air Intercept (AI) radar and the British Night-fighter 1935-1959,* 3-4.; Latham and Stobbs, *Pioneers of radar,* 8-9.; Bowen, *Radar days,* 3-4.; Wood and Dempster, *The Narrow Margin,* 127.; Clark, *Tizard,* 106-108.

technical knowledge can be used to strengthen present methods of defence against hostile aircraft."[144]

Tizard, charged with leading and establishing the committee, immediately recruited several scientists from across the country. Another scientist, R. Watson-Watt, Director of the Radio Research Station at Slough and a leading British radio scientist, believed aircraft would reflect radio energy, which "could be depicted and calibrated on a cathode-ray tube." He was aware, from a report he received in June 1932, that in December 1931 engineers at the British Post Office first detected interference on receivers when aircraft flew past. Watson-Watt, aware of Tizard's efforts, wrote a paper on radio waves and suggested to the committee at its first meeting on 28 January 1935 that it examine radio waves as a means to detect aircraft.[145]

On 12 February 1935, Watson-Watt formally delivered his memorandum on radio waves to the Tizard Committee. The concept to use radio waves to detect aircraft was not new and the committee quickly requested £10,000 for research. Sir Hugh Dowding wanted a demonstration before committing funds, so a test followed on 26 February 1935 using a BBC station and other equipment to detect an aircraft at 8 miles between 1 and 6000 ft. Dowding immediately obtained the funds and made the project MOST SECRET.[146]

By 1 March 1935, the Radio Research Labs located to Orfordness, 90 miles northeast of London for secrecy purposes. By July, the Lab had a radar detecting aircraft at a range of 40 miles.[147] As time progressed,

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[144] Clark, *Tizard, 112*; Jones, *The beginnings of strategic air power: a history of the British bomber force 1923-39*, 86.; Bowen, *Radar days,* viii, 3-4.; White, *The History of the Air Intercept (AI) radar and the British Night-fighter 1935-1959*, 4.; Wood and Dempster, *The Narrow Margin,* 127.
[145] Wallace, *R.A.F. Biggin Hill*, 91.; Jones, *The beginnings of strategic air power: a history of the British bomber force 1923-39*, 86-87.; Latham and Stobbs, *Pioneers of radar,* 9.; Bowen, *Radar days*, vii, 1, 3-4, 6.; Wood and Dempster, *The Narrow Margin,* 128.
[146] White, *The History of the Air Intercept (AI) radar and the British Night-fighter 1935-1959*, 5.; Latham and Stobbs, *Pioneers of radar,* 9-10.; Bowen, *Radar days*, vii, 1.; *Watching the Skies*, p. 3.; Wood and Dempster, *The Narrow Margin,* 128-129.
[147] Latham and Stobbs, *Pioneers of radar,* 10.; Bowen, *Radar days*, 11.

the names and research locations changed. In May 1936, the research section became the Bawdsey Research Station (BRS) at Bawdsey Manor, the Air Ministry Research Establishment (AMRE) on 3 September 1939 with a move to Dundee, followed with a move to Swanage in Spring 1940 and a name change to Telecommunications Research Establishment (TRE).[148]

By 17 June 1935, aircraft detection occurred at 17 miles and 40 by September. Improvements increased the range to 80 miles by the end of 1935, and to 100 by early 1936 for aircraft at 15000 feet.[149] Despite still needing height and azimuth data, progress occurred quickly enough by September 1935 for Watson-Watt to propose a chain of radars to detect incoming aircraft. Height became the next problem to solve.[150] In December 1935, the British Government allocated 1,000,000 pounds for five stations near the Thames estuary with plans for 19 more stations along the east coast and six along the south.[151] The first operational radar at Bawdsey intercepted a KLM flight successfully and continued on its mission to avoid suspicion. Based on this success, the government provided an additional £10 million for the other stations.[152]

Research, development, and trial and error resulted in various radars to meet various operational needs. The first was the Chain Home (CH), or AMES Type 1 radar. CH consisted of a 360 ft steel transmitter tower and a separate 240-foot wooden receiver tower. It provided accurate range, 500-1000 ft height accuracy, 2-degree beam accuracy,

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[148] White, *The History of the Air Intercept (AI) radar and the British Night-fighter 1935-1959*, 29, 58-59.; Wood and Dempster, *The Narrow Margin,* 129-133.; Gough, *Watching the Skies,* 9.; Bowen, *Radar days*, 21-22, 137.; Latham and Stobbs, *Pioneers of radar,* 12.
[149] Bowen, *Radar days* 15-16.; White, *The History of the Air Intercept (AI) radar and the British Night-fighter 1935-1959* 5-6.
[150] Bowen, *Radar days* 21, 26.; Latham and Stobbs, *Pioneers of radar,* 11.
[151] Latham and Stobbs, *Pioneers of radar,* 11-12.; Bowen, *Radar days*, 26-28.
[152] Latham and Stobbs, *Pioneers of radar,* 13.

but was susceptible to jamming. Filter rooms receiving multiple radar feeds/data helped reduce the error.[153]

Chain Home Detection Ranges

Height	Detection Range of Aircraft (Miles)				
	500 ft	1000 ft	3000 ft	15,000 ft	35,000 ft
Sighted at Sea Level	No data	20	45	130	180
Sighted Higher	18	35	120	No data	No data

Table 3[154]

The Chain Home Low (CHL), AMES Type 2, was designed, built, and originally designated in 1939 as a Coastal Defence (CD) radar to counter the low-level flying threat. Realizing CH radars left a low-level coverage gap, the Air Ministry repurposed the existing CD radar as CHL, saving valuable research and production time. Despite providing no height data, it provided very accurate range and bearing data due to its use of short wave lengths, resulting in its use for intercepts.[155]

Chain Home Low Detection Ranges

Height of Station above Sea Level	Detection Range of Aircraft (Miles)				
	100 ft	1000 ft	5000 ft	10,000 ft	25,000 ft
50 ft	8	22	62	90	180
100 ft	10	30	73	105	180
150 ft	10	33	75	107	180
200ft	11	35	80	110	180

Table 4[156]

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[153] Latham and Stobbs, *Pioneers of radar,* 23-24. Latham and Stobbs, *Radar: a wartime miracle,* 15-16, 18.; Gough, *Watching the Skies,* F-1-F-2.
[154] Gough, *Watching the Skies,* F-2.; Latham and Stobbs, *Radar: a wartime miracle,* 17.
[155] Latham and Stobbs, *Pioneers of radar,* page 26.; Gough, *Watching the Skies,* F-3.; Joubert de la Ferté, *The third service; the story behind the Royal Air Force,* 127.; Latham and Stobbs, *Radar: a wartime miracle,* 48-51.
[156] Gough, *Watching the Skies,* F-3.

The most important radar technology developed relating to radar, the cavity magnetron, allowed the production of high power microwaves and the ability to reduce the wavelength to the centimeter range. Centimeter wavelength ensured better accuracy in both height and azimuth and improved low-level coverage. It also provided a more accurate radar ground picture. The technological leap led to new equipment and designs.[157]

While various nations conducted research in magnetrons to produce power at the centimeter wavelengths, the British were the first to produce one for radar. Despite a patent by A. L. Samuel of Bell Telephone Laboratories, in December 1934 for a magnetron with multiple resonators, it was J. T. Randall and H. A. H. Boot who developed the multicavity magnetron in the fall of 1939. AMRE modified the design to create the magnetron, E1189, for centimeter wave radars. The Tizard Mission brought E1189, No 12 to the U.S., which Western Electric and Raytheon copied for use in American radars.[158]

Before the Munich Crisis, just five of the planned 18 CH radars were operational, communications were not connected, underground operations rooms were not built, and no backup electrical supply existed.[159] Luckily, industry was involved early and production had started in the summer of 1937. The Munich Crisis sped up the process, leveraging the knowledge gained in the last year.[160] On Good Friday 1939, CH became operational; operating 24 hours and from then on the RAF practiced its command and control procedures.[161] By 3 September

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[157] Latham and Stobbs, *Pioneers of radar,* 4-5.

[158] E.B. Callick, *Metres to microwaves: British development of active components for radar systems, 1937-1944* (London: P. Peregrinus Ltd. on behalf of the IEE, 1990), 59, 61-64.; Bowen, *Radar days,* 146-147.

[159] Smith, *British air strategy between the wars*, 216.; Gough, *Watching the Skies,* 6.

[160] Wood and Dempster. *The narrow margin; the Battle of Britain and the rise of air power 1930-40,* 136-137, 140.

[161] Joubert de la Ferté, *The third service; the story behind the Royal Air Force,* 126.; Wood and Dempster. *The narrow margin; the Battle of Britain and the rise of air power 1930-40,* 143.

1939 Great Britain had 18 CH radars, 24 more ordered, two independent CH radars, a functioning IFF system, and the new Stanmore Filter Room.[162]

On 12 June 1940, Fighter Command relocated to an underground headquarters where hundreds of men and women plotted aircraft with information received from radar. By then, the system operated efficiently, but only by day.[163] By 1940, Great Britain had 33 CH and 40 CHL operating or procured. At the start of the Battle of Britain, 32 paired CH with CHL radars and 25 CH only radars operated. During the battle, the RAF added an additional 9 CH and 22 CHL radars. By January 1941, 42 CH and 52 CHL were planned or in place.[164]

Air Interception Radar

The British developed AI to solve the night intercept problem shortly after beginning work on the CH radar. The problem initially revolved around how to create a radar set small enough to fit into an aircraft. By 1936, researchers solved the airborne radar receiver problem with the discovery of "a tuned radio-frequency (TRF) receiver designed by the EMI Company for their projected television service." It was small enough, 3 X 18 inches and 20 lbs, to fit in an aircraft. The transmitter problem took until 1937 to solve by getting the transmitter to a 1-meter wavelength, finally settling on 1.5-meter wavelength devices. It used commercial off the shelf materials, such as the famous Western Electric 316A Triode Tube. It had a range of about 3 miles, but by 1939 still could not detect at the required 4 miles.[165] Nonetheless, it worked and the RAF received its first Mark I AI in August 1939. Additionally, the research and development of 1.5-meter wavelength parlayed into other ground radars such as Coastal Defence (CD), Chain Home Low (CHL),

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[162] Gough, *Watching the Skies,* 8.
[163] Edmund Ironside, *Time Unguarded; The Ironside Diaries, 1937-1940* (New York: D. McKay Co., 1963), 362.
[164] Gough, *Watching the Skies,* 8.
[165] Bowen, *Radar Days,* 32-33, 39, 41, 65.; Clark, *Tizard*, 157-158.

Ground Controlled Intercept (GCI), Light Warning (LW), and Searchlight Control (SLC).[166]

IFF

Radar did not solve the problem of identification, only the detection problem. The 1936 exercises first highlighted the need for a system to help distinguish between friend and foe, especially during night intercepts.[167] IFF became the method to distinguish friend from foe.

A friendly IFF return was initially just a larger strobe on a CH radar screen, but soon other methods evolved. One procedural method used an Air Movements Liaison Officer to track friendly aircraft using predetermined routing, but this method did not work well. Another method, called "pip-squeak," used HF/DF equipment sending a 15-second signal from friendly aircraft every minute over the command net.[168]

The first true IFF system arrived in June 1939 and performed well during the Main Home Defence Exercise in August 1939.[169] IFF is composed of three parts; an interrogator, transponder, and responder. The interrogator on the ground sends a signal to an aircraft. The aircraft receives the signal, returns an answer, and the responder receives the signal. A positive signal meant "friend" while a lack of a return signal meant "enemy."[170] This signal, displayed on a fighter controller's Plan Position Indicator (PPI) scope, provided friendly fighter locations.
Tied to the Chain Home radar, the British Mark I IFF system used the radar's antennas and frequencies.[171] The MK II and Mk III IFF improved to cover various radar frequencies,[172] thus increasing interoperability

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[166] Latham and Stobbs, *Pioneers of Radar,* 3, 21.
[167] Gough, *Watching the Skies,* 6.
[168] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 85.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 190.; Gough, *Watching the Skies,* 6.
[169] Gough, *Watching the Skies,* 7, 16.
[170] "IFF: It's Not Doing Its Job," *Radar*, no. 2 (May 1944): 22.
[171] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 85.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 190.
[172] Gough, *Watching the Skies,* 16.

with multiple radar systems.[173] The Mark III designed from the start to work with beacon, IFF, CH, CHL, GCI, GL, and SLC arrived in summer 1942.[174] The Mark III had single receiver/transmitter and became the system adopted by the US and Britain to ensure interoperability. US entrance into the war emphasized the need for IFF and by April 1943, all US and British aircraft had the Mk III.[175]

Conclusion

From November 1918 until September 1939, the United Kingdom explored and developed many doctrinal concepts. The counter-offensive doctrine dominated and drove RAF planning and aircraft development for most of the period. Home Defence, while important and not completely neglected, lagged without civilian guidance. The cult of the offense blinded many to the impact a command and control system with knowledge of enemy movement provided. Despite overwhelming evidence from countless exercises of the devastation to a bomber force from defensive aircraft once aware of the bomber's position, most bomber proponents in the Air Ministry simply ignored the data; even when radar became operational.

While the concept and push for an aircraft detection technology always existed, once again civilians initiated and pushed new technology to help solve the problem. A formal organization not only explored the issue of improving aircraft detection, it also looked at the entire command and control process holistically. As a result, other technologies emerged. Radar helped detect aircraft and then more accurate radar helped control them in complete darkness or bad weather, AI on a fighter provided the fighter with its own "eyes," and finally, IFF helped distinguish friend from foe.

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[173] Ibid, 17.
[174] White, *The History of the Air Intercept (AI) radar and the British Night-fighter 1935-1959*, 145,149.
[175] Gough, *Watching the Skies,* 17.; White, *The History of the Air Intercept (AI) radar and the British Night-fighter 1935-1959,* 145,149.

The United Kingdom built on the procedural command and control concepts developed in WWI, with Ashmore continuing his role in Home Defence into the late 1920s. He lived through WWII to see his lifelong work help save Britain. By the time radar arrived, the RAF had a solid organizational and procedural background to integrate the new technologies into a formidable home defense command and control system. Conversely, almost no progress occurred in the realm of air-to-ground command and control during the interwar period and the UK found itself struggling to remedy the situation after seeing the devastating effects of one in action against Poland and France. The UK's story is, however, not unique.

Chapter 3

The United States During the Interwar Period

As with Great Britain, the US exited WWI ready to demobilize, but unlike the RAF, the Air Service did not have independence and the period found the Air Service and later the Air Corps building a doctrine to support independence. The single-minded drive to develop a strategic doctrine hampered the development of command and control of air forces. By the end of the interwar period, despite two years of watching the war in Europe and seeing Great Britain's command and control system in operation, the failure to fully create and implement a command and control system exposed itself fully and fatally on December 7, 1941.

Command and control development in the US was also evolutionary and it was the Coast Artillery Corps, not the Air Corps that led the development of air-to-air command and control doctrine, processes, and technologies. While some airmen voiced the need for an intelligence and warning network, it was the Coast Artillery Corps that continuously pushed development through the 1920s and early 1930s. Eventually, the Air Corps realized it needed a system. The advent of radar, developed by the Signal Corps for the Coast Artillery Corps, further pushed the Air Corps into developing a command and control system. Finally, with war on the horizon, the Air Corps realized the need for and embraced the need for an air-to-air (air defense) command and control system.

Despite the US being one of the few countries in the world to maintain ground attack squadrons throughout the interwar period, it made no effort to develop an air-to-ground system. The US rapidly created both air-to-air and air-to-ground systems once political and military leaders thought war inevitable. They were not however fully ready for war even with two additional years of preparation.

The Political and Economic Situation

The US reverted to isolationism after "the war to end all wars," maintaining minimal military forces barely capable of defending the "continental United States, Oahu, and the Panama Canal."[1] An official isolationist national policy coupled with fiscal constraints led to an almost immediate demobilization of the large forces created to fight in Europe.

The Air Service was very expensive and in the wake of public indifference toward military preparedness, post war cuts across the military were unavoidable.[2] Even the public's growing enthusiasm for aviation did not help the Air Service although it fared better than other branches. Little sympathy existed even at the highest levels; President Coolidge expected money for air to come out of the budget from other branches of the Army if necessary[3] to reduce military spending.

In terms of personnel, the Air Service grew from 51 personnel on 1 November 1912 to 1,152 on 6 April 1917, 138,997 by 30 June 1918 and 51,229 by November 11, 1918. By 1919, in the midst of demobilization, personnel dwindled to 24,115 and by 1920 to 9,358. At war's peak, the Air Service had 20,000 officers, down to 200 after demobilization. The Army Air Forces would not reach those peak numbers again until 1941. Facing budgetary restrictions, parsimony in the Budget Bureau, and pacifism in Congress, the Air Service went from a wartime appropriation of $460 million in FY19 (1 July 1918), rising eventually to $73 million in

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[1] Stetson Conn and Byron Fairchild, *The Framework of Hemisphere Defense* (Washington,: Office of the Chief of Military History Dept. of the Army, 1960), 3.
[2] *USAF Historical Study No, 20, Comparative History of research and Development Policies Affecting Air Materiel 1915-1944* (Prepared by AAF Historical Office Headquarters, Army Air Forces, June 1945), 30.; J.C. Haw, Major, "Antiaircraft Defense," *Coast Artillery Journal* (October, 1925): 328.
[3] Tate, James P. Tate, *The Army and its Air Corps: Army Policy Toward Aviation, 1919-1941* (Maxwell Air Force Base, Ala: Air University Press, 1998), 60-61.

1939.[4] This was not a uniquely American phenomenon. Within 3 years of WWI, the aviation industries in some countries almost ceased to exist.[5]

Air Service Appropriations								
FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY39
$460M	$25M	$33M	19.2M	$12.9M	$12.6M	$12.8M	$15M	$73M

Table: 5[6]

During the Great Depression budgets tightened and funds allocated to the military shrank further, causing the Air Corps to cancel its FY 1932 exercises.[7] By 1932, defense was 15% of the US budget and President Roosevelt continued the cost-cutting trend in 1933, making it 9% of the budget. Examples of the cuts include the suspension of the *Air Corps Newsletter* from October 1933 to January 1935 and the reduction of hours for pilots by approximately 20% from 200 to 160 hours a year.[8]

With the country's inward focus, defensive posture, and economic problems after 1929, the Army now viewed its primary mission as continental defense. Offensive operations were so abhorred the Air Corps used air defense as an argument for more money (planes). The Air Corps developed its strategic bombing theory under the blanket of coastal

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[4] *Army Air Forces Statistical Digest World War II* (Prepared by Office of Statistical Control, December 1945), 15.; Patrick, *The United States in the Air*, 9, 49.; Tate, *The Army and its Air Corps,* 7, 31.; Maurer Maurer, *Aviation in the U.S. Army, 1919-1939* (Washington, D.C.: Office of Air Force History, U.S. Air Force, 1987), 44-46.; *Army Air Forces Historical Studies No. 50, Materiel Research and Development in the Army Air Arm 1914-1945* (AAF Historical Office, Headquarters, Army Air Forces, November, 1946), 50.; *Army Air Forces Historical Studies No, 22, Legislation Relating to the AAF Materiel Program, 1939-1945* (Air Historical Office, Headquarters, United States Air Force, August, 1949), 162.

[5] Morrow, *The Great War in the Air,* xiii.

[6] *Army Air Forces Statistical Digest World War II*, 15.; Patrick, *The United States in the Air,* 9, 49.; Tate, *The Army and its Air Corps,* 7, 31.; Maurer, *Aviation in the U.S. Army, 1919-1939*, 44-46.; *Army Air Forces Historical Studies No. 50, Materiel research and Development in the Army Air Arm 1914-1945,* 50.; *Army Air Forces Historical Studies No, 22, Legislation Relating to the AAF Materiel Program, 1939-1945*, 162.

[7] Letter, "Air Corps Command and Staff Exercise," by Brigadier General O. Westover, Assistant Chief Air Corp, May 18, 1932, Call # 248.2122-2, 1932, in the USAF Collection, AFHRA, Maxwell AFB AL.

[8] Maurer, *Aviation in the U.S. Army, 1919-1939,* 348.

defense,[9] emphasizing it provided area defense until the location of an attack could be determined.[10]

Despite budgetary struggles, the Army slowly grew in size between 1925 and 1939. Air Corps funding increased from $30 million in 1935 to $73 million in 1939.[11] When the Air Corps began carrying the mail in 1934, Congress questioned aircraft quality and pilot proficiency, bringing both increased scrutiny and an additional $5 million in funding. Events across the world such as war in Spain, China, Ethiopia, and the Munich Crisis in September 1938 changed American thinking, at least at the top, and the size of the Army increased dramatically.[12] On 14 November 1938, President Franklin D. Roosevelt declared, "the United States must be prepared to resist attack on the Western Hemisphere from the North Pole to the South Pole, including all of North America and South America."[13]

As a result, the President pressed for a large expansion of the Air Corps to 10,000 planes and an annual aircraft production of 10,000, coupled with a program for hemisphere defense, eventually calling for up to 50,000.[14] Either President Roosevelt believed German aggression in Europe would eventually lead to German expansion or influence in the Americas, or he foresaw the United States drawn into a European war. His actions hedged either possibility. Although mobilizing American military and industrial capability would take time and had to overcome isolationist sentiment in the public and within Congress, Roosevelt positioned the nation toward a war footing.

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[9] Thomas H. Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941* (Washington, D.C.: Office of Air Force History, U.S. Air Force, 1985), 15.
[10] Tate, *The Army and its Air Corps,* 136-137.
[11] *Army Air Forces Historical Studies No. 22, Legislation Relating to the AAF Materiel Program, 1939-1945*, 162.
[12] Maurer, *Aviation in the U.S. Army, 1919-1939,* 346, 350.
[13] Conn and Fairchild, *The Framework of Hemisphere Defense*, 3-4, 15.
[14] Conn and Fairchild, *The Framework of Hemisphere Defense*, 4-5, 16.; Tate, *The Army and its Air Corps,* 172.

Airpower's potential ability to attack the United States from far away with little notice or warning served as an impetus for enlarging the Air Forces, the first part of the Army to expand in line with the new hemisphere defense policy.[15] Congress' response to Roosevelt's call on 12 January 1939 for 10,000 airplanes was to approve $300,000,000, for 3,000 airplanes in the April and June 1939 appropriations acts. These airplanes, scheduled for mid-1941, brought the Air Corps inventory from 1,700 to 5,500 aircraft, with 3,300 being combat planes within 24 combat-ready Groups.[16] Because its primary mission was Hemisphere Defense, the Air Corps was able to justify the procurement of 250 B-17s within the 5,500 aircraft plan.[17] By the end of 1939, the Air Corps had 1800 planes with an additional 1350 delivered by May 1940. The increased funding also added other items, accessories, people, and training to the Air Corps.[18] Providing aircraft to France and Britain slowed the acquisition process, but none-the-less, the Air Corps started receiving the funding to prepare for war.

Organization

Airpower's Place in the Army

World War I did not immediately change airpower's position as a supporting part of the Army. Despite some autonomy achieved in Europe for independent missions, General Pershing clearly placed those missions below supporting ground troops.[19] Several post WWI boards, the

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[15] Conn and Fairchild, *The Framework of Hemisphere Defense*, 16.

[16] Wesley Frank Craven and James Lea Cate, *The Army Air Forces in World War II: V.1. Plans and Early Operations, January 1939 to August 1942* (Chicago: University of Chicago Press, 1948), 104.; Conn and Fairchild, *The Framework of Hemisphere Defense*, 17.; Major General H.H. Arnold, "Aircraft Production under the Army Air Expansion Program," *U.S. Air Services* Vol XXV, no. 4 (April, 1940): 9.; Tate, *The Army and its Air Corps*, 171.; United States, *Report of the Commanding General of the Army Air Forces to the Secretary of War* (Washington, D.C., 1944), 6.

[17] Tate, *The Army and its Air Corps, 171.;* United States, *Report of the Commanding General of the Army Air Forces to the Secretary of War*, 6.

[18] Maurer, *Aviation in the U.S. Army, 1919-1939,* 350.

[19] Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, 3.; John F. Shiner, *Foulois and the U.S. Army Air Corps, 1931-1935* (Washington, D.C.: Office of Air Force History, United States Air Force, 1983), 12.

Dickman Board and the Menoher Board, along with Congressional reports, firmly reaffirmed the supporting role, calling "for unity of command and no independence for the air arm."[20] While aviation would remain an auxiliary service under the control of a ground commander, the National Defense Act of 1920 officially made the air service an Army branch,[21] and a combatant arm on the same level as the Infantry, Cavalry, and Artillery. It also became responsible for developing and acquiring its own equipment.[22]

Despite failing to convince the various boards for co-equal status with the Army and Navy, General Mitchell garnered support in Congress, resulting in the Army Appropriation Act for the 1921 fiscal year. It provided "that here after the Army Air Service shall control all aerial operations from land bases, and Naval Aviation shall have control of all aerial operations attached to a fleet, including shore stations whose maintenance is necessary for operation connected with the fleet, for construction and experimentation and for the training of personnel."[23] This extremely important Act set the legal foundation for the role the Coastal Artillery Corps and Air Service played in coastal defense and hence the development of the command and control concepts and technologies used during World War II. The Air Corps later sold the B-17 as a way to do the coastal defense mission due to its long range, firepower, and ability to destroy an enemy before coming close to US borders.[24] The enthusiasm for coastal defense was not new; the Air

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[20] Tate, *The Army and its Air Corps,* 7-12.; Maurer, *Aviation in the U.S. Army, 1919-1939,* 40-41.; Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, 21-24.; Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force* (Maxwell Air Force Base, Ala: Air University Press, 1989), 29-31.
[21] Patrick, *The United States in the Air*, 75-76.; Tate, *The Army and its Air Corps,* 14.
[22] Maurer, *Aviation in the U.S. Army, 1919-1939,* 44.; Robert Frank Futrell, *Ideas, Concepts, Doctrine*, 35.; Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, 25.; Shiner, *Foulois and the U.S. Army Air Corps, 1931-1935*, 12-18.
[23] Robert Frank Futrell, *Ideas, Concepts, Doctrine*, 35.
[24] Tate, *The Army and its Air Corps,* 166.

Service had embraced the coastal defense mission since the end of the war.[25] The Act also set up budgetary fights between the Army and Navy.

During the next two fiscally constrained decades, homeland defense became the only mission politically palatable. The Air Service found itself in the middle due to its and the Army's interest in keeping coastal defense for budgetary reasons[26] and the Navy's interest in trying to find a way to show its relevance to homeland defense in the face of the Air Service's very public airpower demonstrations of what airpower could do to battleships. Mitchell also recommended an air force with antiaircraft under its control for the coastal and frontier defense mission. In 1925, the Chief of the Air Service, General Mason Patrick asked for more aircraft and studies to determine the airplane's suitability for coastal defense.[27] A War Department Board of Officers met on March 14, 1925, comprising the Chief of Coast Artillery, Chief of Ordnance, Chief of Air Service, and Assistant Chief of Staff, G-3 to formulate a program of AAA and Air Corps exercises approved by the War Department to test and improve AAA firing and detection via devices.[28] Mitchell and Patrick's recommendations shrewdly carved out a niche for the Air Service to ensure funding and a position within the Army.

The traditional Army continued to hold sway in spite of agitation from vocal airman such as Mitchell, but some progress towards providing the Air Service room for independent air operations occurred. The budgetary toll resulted in the 1923 Lassiter Board as the Army pursued ways to improve airpower. In the end, the Army was not willing to change the way it viewed airpower relative to ground forces. The board concluded the observation, attack, and pursuit air arms should remain part of the division, corps, and armies with a reserve in the General Headquarters

[25] Maurer, *Aviation in the U.S. Army, 1919-1939,* 108.
[26] Tate, *The Army and its Air Corps,* 67.
[27] Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, 34-35.
[28] "Report of Antiaircraft Service and Air Service Exercises, Ft Tilden NY & Ft Dix, NJ," 1925, Call # 248.2124-5, in the USAF Collection, AFHRA, Maxwell AFB AL.

(GHQ). However, a third arm for strategic or special missions with or without ground cooperation was created within the GHQ.[29] This is the first official acknowledgment of strategic missions.[30]

The 1925 Morrow Board, held under the auspices of improving the use of aircraft, but really an Army and Navy attempt to maintain their air arms, concluded the US was in no danger from attack and strategic bombing would not break a nation's will. Despite recommending against creating a department of national defense or a department of air,[31] it did recommended the Air Service become the Air Corps with representation on the General Staff. With the passing of the Air Corps Act, the Air Service became the Air Corps on 2 July 1926. The same act created the Air Service Field Officer's School at Langley Field, Virginia.[32]

The next major organizational change occurred on 1 March 1935 with the creation of the General Headquarters Air Force (GHQ AF). This centralized control over all tactical air units in the US under a single commander and gave the Commanding General, GHQ AF, "full control and responsibility for the peacetime development and training of aviation and means and methods of air defense."[33] Airpower provided a mobile force for defense and the ability to conduct independent missions.[34] GHQ AF became the means for exerting "Air Power."[35] Beginning in March 1939 the commander, GHQ AF, fell under the Chief of the Air Corps versus the Chief of Staff, with continental coastal defense as its principal mission. This further increased ambiguity because although the army

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[29] Tate, *The Army and its Air Corps,* 20.; Futrell, *Ideas, Concepts, Doctrine*, 42-43.
[30] Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, 27.
[31] Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, 29.; Tate, *The Army and its Air Corps,* 41-47.; Futrell, *Ideas, Concepts, Doctrine*, 48.
[32] Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, 29.; Futrell, *Ideas, Concepts, Doctrine*, 50.; Shiner, *Foulois and the U.S. Army Air Corps, 1931-1935*, 23-31.
[33] Conn and Fairchild, *The Framework of Hemisphere Defense*, 14.; Conn, *Guarding the United States and Its Outposts*, 29.; Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, 73.; Futrell, *Ideas, Concepts, Doctrine*, 74.; *Air Corps Newsletter*, V8110. A.C., 1 August 1939, 22.
[34] Tate, *The Army and its Air Corps,* 139-142.
[35] *Air Corps Newsletter*, V8110. A.C., 1 August 1939, 22.

and corps lost control of air units, the army and corps commanders still had responsibility for defense planning.[36] Secretary of War, Henry L. Stimson called it a “perfectly screwball arrangement.” In November 1940, Arnold became the deputy chief of staff under Marshall, but retained the title of Chief of the Air Corps in an attempt to fix the “perfectly screwball arrangement” of the command structure.[37]

Thinkers and Theorists

Unlike in Britain, Douhet’s impact on doctrine in the United States is clear. American interwar doctrine expressed Douhet’s ideas, and they had a demonstrable impact on command and control development. His ideas are so well known that they warrant only a cursory examination. Douhet advocated the offensive use of airpower and did not value defense. He noted the difficulty of knowing the exact time and location of the enemy’s thrusts, rejected the ability to intercept bombers, and dismissed the ability to defend with ground equipment.[38] In his view, the best defense was a good offense, with command of the air gained by striking the enemy air force at its bases where they are most vulnerable. The sky’s vastness also reduced the chances of meeting enemy fighters in the air.[39]

Oddly, while advocating the need for pursuit escort to clear the skies, he later envisioned well-armed bombers getting the better of pursuit aircraft. He eventually advocated the development of a “battleplane” by combining a bomber and escort plane into a single aircraft. The B-17 Flying Fortress was the manifestation of the idea. He also discussed the importance of intelligence, but failed to discuss a method of using the information for defensive purposes. Finally, he

[36] Conn, *Guarding the United States and Its Outposts*, 19, 54.; Tate, *The Army and its Air Corps,* 178.; *Air Corps Newsletter*, V8110. A.C., 1 Aug 1939, 22.
[37] Tate, *The Army and its Air Corps,* 178.
[38] Giulio Douhet and Dino Ferrari, *The Command of the Air*, (Washington, D.C.: Air Force History and Museums Program, 1998), 9, 17, 55,111-112.
[39] Ibid, 18-19, 55.

advocated breaking the will of the people by attacking vital centers.[40] These ideas affected the development of command and control, serving as intellectual blinders to other views.

General William Mitchell, the most famous American airpower advocate, also had a profound effect on the development of American airpower doctrine. He believed in the need for air superiority; attained by attacking the enemy air force. During WWI, many airpower observers thought the bomber could defend itself with its own defensive fire, but this proved wildly optimistic. Mitchell concluded, "Bombardment raids have to be protected by Pursuit Aviation." Post WWI, pursuit aircraft remained the most dominant aircraft for a time, but that position slowly changed due to technological changes. Finally, as did other leading air power advocates from other nations, he called for attacking centers of production.[41]

Despite his experience with a successful command and control system in WWI between AAA, aerodromes, searchlights and headquarters tied together via radio and telegraph, General Mitchell thought "the whole arrangement of ground protection against aircraft, sound ranging, searchlights and guns cannot stand up under intelligent air attack and is incapable of serious effects on airplanes." He also thought, "it cannot be told with certainty from what direction the opposing aircraft are coming; therefore it is necessary to completely surround the locality to be defended with observation and listening posts, both in the air and on the ground." A proper defense included both air and ground defense, and with the connectedness of a command and control system air forces could concentrate quickly where needed, at the decisive point.[42]

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[40] Ibid, 19, 34-35, 41, 44-45, 117-120.

[41] William Mitchell, Skyways: A Book on Modern Aeronautics (Philadelphia: J.B. Lippincott company, 1930), 253-255.; William Mitchell, *Winged Defense: The Development and Possibilities of Modern Air Power, Economic and Military* (Mineola, N.Y.: Dover Publications, 2006), 16, 199.; Mitchell, *Our Air Force, The Keystone of National Defense*, 16, 41, 46, 60.

[42] Mitchell, *Winged Defense,* 204-207.; Mitchell, *Our Air Force*, 21-22, 32.

Despite his advocacy for an independent air force, Mitchell called for joint operations under a single commander. He stated that war is decided on the ground, but successful operations require branch cooperation. Finally, in line with concentrating airpower under a single commander for a common objective, he thought all air operations should be placed in an "aeronautical plan of employment," that is an official order.[43]

Thoughts from the Air Corps Tactical School

The Air Service opened the Air Services Field Officers School at Langley Field, Virginia, in November 1920. "The bulk of the course dealt with tactical employment of aviation. The seven officers in the first class also studied navigation, meteorology, communications, photography, armament, history of the Air Service, Army regulations, field service regulations, military law, and hygiene and sanitation." In 1922, the school became the Tactical School, added practical flying activities in 1923, and eliminated technical areas in 1925 to focus on aviation tactics and techniques. This included flying, application of theories, and participation in exercise and other field visits. Instructors wrote the manuals and texts. [44] The first, written by Maj. William C. Sherman in 1921, entitled *The Fundamental Doctrine of the Air Service*, already reflected the thought of independent air operations and the impact of strategic bombing.[45] Following the passage of The Air Corps Act of 1926, the school became the Air Corps Tactical School.[46] Reflecting the Army

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[43] William Mitchell, *Our Air Force*, 18, 222.

[44] Maurer, *Aviation in the U.S. Army,* 64-65.; Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, 16, 29.; Robert T. Finney, *History of the Air Corps Tactical School, 1920-1940* (Washington, D.C.: Center for Air Force History, 1992), 21-22.; Futrell, *Ideas, Concepts, Doctrine*, 62.; Shiner, *Foulois and the U.S. Army Air Corps, 1931-1935*, 44.; *Air Corps Newsletter*, V8110, A.C, 1 August, 1938, 9.

[45] Maurer, *Aviation in the U.S. Army,* 65.; Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*,16.; Futrell, *Ideas, Concepts, Doctrine*, 40.

[46] Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, 29-30.; Futrell, *Ideas, Concepts, Doctrine*, 62.; Finney, *History of the Air Corps Tactical School, 1920-1940*, v.; John F. Shiner, *Foulois and the U.S. Army Air Corps, 1931-1935* (Washington, D.C.: Office of Air Force History, United States Air Force, 1983), 44.

culture of combined arms, cross branch exposure began in the 1930-1931 school year after the Secretary of War directed ten officers from other branches to attend the Air Corps Tactical School with two allotments to Infantry, Field Artillery, Cavalry and Coast Artillery, and one officer each from the Corps of Engineers and the Signal Corps.[47] In 1931, the school moved from Langley to Maxwell Field, Alabama.[48]

Major Sherman's text, *The Fundamental Doctrine of the Air Service*, built on a tentative doctrinal manual created under Colonel Edgar S. Gorrell's guidance, continued to hold airpower's place as a supporting arm of ground operations, despite addressing independent air operations and the impact of strategic bombing.[49] Initially, the ACTS taught the same concept and while the Air Service continued to see air superiority and ground support as its main missions, the idea of bombardment and its ability to determine wars by crushing the enemy's will slowly began to appear in the school's texts as early as 1924.[50]

> [Bombardment] must surmount every obstacle to accomplish its mission. *This, in fact, is the basic doctrine of bombardment aviation.* The defenses against aviation are numerous; their powers real. *But no matter how numerous or how powerful they may be, they will not prevent bombardment from accomplishing its assigned missions……………….* Bombardment will reach and destroy its objectives."[51]

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47 "Allotment of Officers to Air Corps Tactical School," *Air Corps Newsletter* (Office of the Chief of the Air Corps, War Department, Washington, February 6, 1930), 25.; "Assignment of Officers of Other Branches to Air Corps Tactical School," *Coast Artillery Journal* (February, 1931): 141.

48 Finney, *History of the Air Corps Tactical School, 1920-1940*, v.; Shiner, *Foulois and the U.S. Army Air Corps, 1931-1935*, 44.; *Air Corps Newsletter* (Office of the Chief of the Air Corps, War Department, Washington, 1 August 1938), 9.

49 Maurer, *Aviation in the U.S. Army,* 65.; Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, 15-16.; Futrell, *Ideas, Concepts, Doctrine*, 40.

50 ACTS Text, "Bombardment Aviation 1924/1925," ACTS, Langley Field VA, Call # 248.101-9, USAF Collection, AFHRA, Maxwell AFB AL.

51 ACTS Text, "Bombardment Aviation 1924/1925," ACTS, Langley Field VA, p. 20-21, Call # 248.101-9, USAF Collection, AFHRA, Maxwell AFB AL. [emphasis in the original]

The texts changed very little from 1925/1926 to 1926/1927 despite disagreement regarding bombardment's efficacy.[52] The school viewed defenses as unable to stop bombardment from reaching targets, but admitted defensive systems would cause damage to bombardment aircraft, as they did to German bombers attacking Paris in September 1918. The high cost of making AAA to stop bombardment became the reason for explaining the emphasis.[53] At the same time, bombardment needed pursuit escort to help neutralize enemy pursuit when expecting opposition,[54] as conceptualized in the school's emerging concept of supported and unsupported raids.[55] The underlying message of this concept was that strong enemy defenses might indeed be able to prevent a successful bombardment mission.[56] Despite the growing strength of the bombardment adherents, recent history proved the bomber was vulnerable to air defenses, from both the air and ground. In accordance with the Army's defensive mission, the text also discussed the cooperative nature of bombardment with the Coastal Artillery Corps.[57]

Pursuit concepts learned from World War I became enshrined in two Army training regulations, *TR 440-70 Pursuit Aviation, 1923* and *TR 440-80 Air Service: The Pursuit Squadron, 1923*. According to *TR 440-70*, pursuit gained air superiority and protected observation aircraft and ground troops. Sound ranging and detection stations, searchlights, and listening posts aided pursuit aircraft and provided a ground

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[52] ACTS Text, "Air Force-The Employment of Combat Aviation 1925-1926," ACTS, Langley Field VA, Call # 248.101-7A, USAF Collection, AFHRA, Maxwell AFB AL.; ACTS Text, "Bombardment Aviation 1926/1927," ACTS, Langley Field VA, Call # 248.101-9, USAF Collection, AFHRA, Maxwell AFB AL.
[53] ACTS Text, "Bombardment Aviation 1926/1927," ACTS, Langley Field VA, Call # 248.101-9, p. 73, USAF Collection, AFHRA, Maxwell AFB AL.
[54] ACTS Text, "Bombardment Aviation 1926/1927," ACTS, Langley Field VA, Call # 248.101-9, p. 14, 78, USAF Collection, AFHRA, Maxwell AFB AL.
[55] J. T. McNarney, Major, "The Influence of Air Power on Coast Defense," *Coast Artillery Journal* (October, 1925): 333-334.
[56] ACTS Text, "Bombardment Aviation 1924/1925," ACTS, Langley Field VA, Call # 248.101-9, p. 45, USAF Collection, AFHRA, Maxwell AFB AL.
[57] ACTS Text, "Bombardment Aviation 1926/1927," ACTS, Langley Field VA, Call # 248.101-9, p. 78, USAF Collection, AFHRA, Maxwell AFB AL.

communications network to tie in with command, AAA, aerodromes, searchlights, and sound and listening stations. The communication network included telephones, radio and a messenger service. Defensive areas had subsectors and alert aircraft to intercept incoming aircraft.[58] All concepts carried over from WWI. *TR 440-80* discussed the need for interflight and air-to-ground communications and the need to rely on searchlights, listening devices and radios for night operations.[59] Together these documents, without using the terms "command and control system," "air warning net," or "air warning service," laid out the necessary elements of a command and control system.

The Pursuit Text of 1929, from a command and control perspective embraced these already well-established ideas; the use and effectiveness of an alert system, the requirement for good communications, good intelligence and the rapid flow of information. The dearth of improvement in radio performance since the war and the "lack of adequate communications is probably the greatest stumbling block in the development of air tactics," limiting the ability to control aircraft from the ground. Interestingly, the text discussed the use of drop tanks to extend the range and airborne time of pursuit aircraft.[60]

Sherman's ACTS text informally became *Training Regulation No.440-15, Fundamental Principles for the Employment of the Air Service*,[61] before officially becoming *TR 440-15, Fundamental Principles for the Employment of the Air Service*, dated 26 January 1926. It stated, "The mission of the Air Service is to assist the ground forces to gain strategical and tactical success by destroying enemy aviation, attacking enemy ground forces and other enemy objectives on land or sea, and in

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[58] *TR 440-70, Pursuit Aviation, 1923*, Call # 248.282-39, USAF Collection, AFHRA, Maxwell AFB AL.
[59] *TR 440-80, Air Service: The Pursuit Squadron, 1923*, Call# 248.282-38, in the USAF Collection, AFHRA, Maxwell AFB AL.
[60] ACTS Text, "Pursuit Aviation," 1929, ACTS, Langley Field VA, , Call # 248.101-8, pp. 137, 166, in the USAF Collection, AFHRA, Maxwell AFB AL.
[61] Futrell, *Ideas, Concepts, Doctrine*, 41.

conjunction with other agencies to protect ground forces from hostile aerial observation and attack." Other missions included observation, reconnaissance, artillery spotting, and transportation. It stressed the importance of communications between aircraft, between air and ground, and the cooperation necessary between AAA and pursuit. Not only did it assign various aircraft types to Divisions, Corps, or Armies, but also the aircraft assigned to a General Headquarters Air Force (comprised mainly of bombardment and pursuit aircraft). Conceptually, the GHQ provided the organizational structure to leverage the speed and mobility of air forces to rapidly deploy and concentrate forces to defend against an attack on the US. Unlike air power assigned to ground commanders, air forces under GHQ could and probably would operate within the theater of operations to support ground forces or beyond, but would also conduct strategic missions.[62] *TR 440-15's* wording providing for a GHQ, despite subordinating most air power under a ground commander, gave airpower advocates at the ACTS an opening to expound on independent bomber action. School texts began reflecting this concept, gaining momentum through the late 1920s.

While strategic bombing doctrine continued to grow and gain proponents within the Air Corps, airmen still considered pursuit necessary for offensive action, denying the enemy freedom of action,[63] and most importantly for the time, for its role in coastal defense.[64] The coastal defense mission also justified the development and purchase of

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[62] War Department, *Training Regulations TR 440-15, Fundamental Principles for the Employment of the Air Service* (Washington, 26 January 1926), Call # 107.108, USAF Collection, AFHRA, Maxwell AFB AL.

[63] Study, "Pursuit Aviation," 1931-1932, ACTS, Maxwell Field, AL, Call # 248.242-8, p. 1, in the USAF Collection, AFHRA, Maxwell AFB, AL.; ACTS Text, "The Air Force," ACTS, Langley Field VA, April 1930, Call # 248.101-1, p. 72-73, in the USAF Collection, AFHRA, Maxwell AFB AL.; ACTS Text, "The Air Force," ACTS, Langley Field VA, February 1931, Call # 248.101-1, p. 49, in the USAF Collection, AFHRA, Maxwell AFB AL.; ACTS Text, "The Air Force, 1933-1934," ACTS, Maxwell Field AL, Call # 248.101-7, pp. AF-1, 3, in the USAF Collection, AFHRA, Maxwell AFB AL.

[64] Study, "Pursuit Aviation," 1931-1932, ACTS, Maxwell Field, AL, Call # 248.242-8, p. 29, in the USAF Collection, AFHRA, Maxwell AFB, AL.; ACTS Text, "The Air Force, April 1930," Langley Field VA, Call # 248.101-1, p. 110, in the USAF Collection, AFHRA, Maxwell AFB AL.

the B-17 because long-range bombardment attacked invading forces far from the coast adding depth to the defensive system.[65] Over time however, pursuit's importance, due to various factors, declined until the late 1930s.

A study conducted in 1931 highlighted the neglect of pursuit development in the US.[66] Neglect resulted in lagging pursuit capability relative to bombers and further contributed to the idea of pursuit's inferiority. Pursuit advocates at ACTS in 1930 discussed the need for improved aircraft, commenting on the use of drop tanks to extend pursuit range.[67] Limited range hampered pursuit's ability to conduct defensive operations, but could overcome this limitation if placed on alert, provided information on inbound enemy aircraft, and employed in large numbers.[68]

The 1930 text highlighted the lack of consensus regarding the strengths and limitations of bombardment aviation. Despite the rhetoric that the bomber would get through with minimal damage,[69] ACTS texts throughout the 1930s emphasized the real and vigorous enemy pursuit threat and the need for friendly escort to "drive home the bombardment attack."[70] If the bomber could not get through and enemy pursuit did disrupt operations, then bombardment would simply shift to night

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[65] ACTS Text, "The Air Force, February 1931," ACTS, Langley Field VA, Call # 248.101-1, p. 73, in the USAF Collection, AFHRA, Maxwell AFB AL.; ACTS Text, "The Air Force, April 1930" ACTS, Langley Field VA, Call # 248.101-1, p. 110, in the USAF Collection, AFHRA, Maxwell AFB AL.

[66] Study, "Pursuit Aviation," 1931-1932, ACTS, Maxwell Field, AL, Call # 248.242-8, p. 2, in the USAF Collection, AFHRA, Maxwell AFB, AL.;

[67] ACTS Text, "The Air Force, April 1930," ACTS, Langley Field VA, Call # 248.101-1, p. 55, in the USAF Collection, AFHRA, Maxwell AFB AL.

[68] Study, "Pursuit Aviation," 1931-1932, ACTS, Maxwell Field, AL, Call # 248.242-8, p. 21, 29, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[69] ACTS Text, "Bombardment Aviation," December 13, 1930, ACTS, Langley Field VA, Call # 248.101-9, p. 113, in the USAF Collection, AFHRA, Maxwell AFB AL.

[70] ACTS Text, "Bombardment Aviation," November 1, 1935, ACTS, Maxwell Field AL, Call # 248.101-9, pp. 119, 141, in the USAF Collection, AFHRA, Maxwell AFB AL.; ACTS Text, "Bombardment Aviation," October 1933, ACTS, Maxwell Field AL, Call # 248.101-9, pp. 106-107, in the USAF Collection, AFHRA, Maxwell AFB AL.; ACTS Text, "Bombardment Aviation," December 13, 1930, ACTS, Langley Field VA, Call # 248.101-9, pp. 114, 117, in the USAF Collection, AFHRA, Maxwell AFB AL.

operations[71]—this idea contradicted the idea the bomber would get through.

Aircraft performance contributed to pursuit's decline relative to bombardment, leading many to believe that as bomber speeds increased, the probability of interception decreased.[72] The school discussed various experiments and field exercises showing pursuit had difficulty intercepting bombers.[73] For example, the Ft Knox Exercise of 1933 demonstrated pursuit's difficulty in intercepting low-flying planes,[74] but did not comment on successful intercepts at higher altitudes.

While an instructor at ACTS, Major Claire Chennault, the most famous and vocal pursuit proponent, identified the need and requirements for an aircraft reporting service for day and night pursuit aviation. These requirements remain the basic elements still used today: "To detect, locate, and report approximate position of hostile aircraft at frequent intervals."[75] He drew these requirements from a study of WWI history.[76] As early as 1933, he believed and showed that air defense could disrupt an attacker, but all the elements to make the system effective were still missing. In 1933, he wrote a three-part series in the *Coast Artillery Journal*, "The Role of Defensive Pursuit." In these three articles, he clearly presented the rationale and organizational design of a command and control system for defense. The principles discussed are very similar to those developed in Great Britain. In fact, the ACTS library, since its time at Langley Field, Virginia, had a copy of Ashmore's 1929

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[71] ACTS Text, "The Air Force," April 1930, ACTS, Langley Field VA, Call # 248.101-1, p. 55, in the USAF Collection, AFHRA, Maxwell AFB AL.
[72] ACTS Text, "Bombardment Aviation," December 13, 1930, ACTS, Langley Field VA, Call # 248.101-9, p.114, in the USAF Collection, AFHRA, Maxwell AFB AL.
[73] ACTS Text, "Bombardment Aviation," February 1931, ACTS, Maxwell Field AL, Call # 248.101-9, p. 120-121, in the USAF Collection, AFHRA, Maxwell AFB AL.
[74] ACTS Text, "Bombardment Aviation," October 1933, ACTS, Maxwell Field AL, Call # 248.101-9, p. 133, in the USAF Collection, AFHRA, Maxwell AFB AL.
[75] Major Claire L. Chennault, "Pursuit in Cooperation with Antiaircraft Artillery," *The Coast Artillery Journal* LXXVIII, no. VI (November-December 1935): 421-22.
[76] Ibid, 422.

Air Defense, which Chennault definitely read as he referenced the book in a 1935 *Coast Artillery Journal* article entitled, "Pursuit in Cooperation with Antiaircraft Artillery." An exercise at Maxwell Field in December 1934 tested one bomber against one pursuit, four searchlights, and the Aircraft Reporting Service.[77] The post exercise report noted the need for sound detectors and other devices to find aircraft, a unified command, and observation-listening posts for frequent updates,[78] thus mirroring the conclusion of almost all reports on the subject from the end of WWI to the start of WWII.

After Major Chennault left ACTS, Captain Gordon P. Saville took his place as the main advocate for pursuit aircraft. He was not as confrontational as Chennault, only arguing the importance of defense, not its dominance over offense. Despite being less antagonistic towards the bomber advocates, Captain Saville did not make headway. It required intervention by General Arnold to get the Air Corps to develop its command and control capabilities.

The school also addressed joint defense capability in various texts. These texts addressed the use of searchlights and sound locators to detect aircraft,[79] the need for joint operations to attain local air superiority, the idea of a single air defense commander to maximize the effects of pursuit and AAA (together they maximize defense),[80] the difficulty of joint operations,[81] the enemy's use of an observation

[77] Ibid, 422.
[78] Ibid, 422-423.
[79] ACTS Text, "Antiaircraft Artillery," November 1, 1932, ACTS, Maxwell Field AL, Call # 248.101-20, pp. 1, 35-37, in the USAF Collection, AFHRA, Maxwell AFB AL.
[80] ACTS Text, "Antiaircraft Artillery," November 1, 1932, ACTS, Maxwell Field AL, Call # 248.101-20, p. 11, in the USAF Collection, AFHRA, Maxwell AFB AL.; ACTS Text, "Air Force-The Employment of Combat Aviation," 15 April 1937, ACTS, Maxwell Field AL, Call # 248.101-7, p. 35, in the USAF Collection, AFHRA, Maxwell AFB AL.
[81] ACTS Text, "Antiaircraft Artillery," November 1, 1932, ACTS, Maxwell Field AL, Call # 248.101-20, p. 11, in the USAF Collection, AFHRA, Maxwell AFB AL.

network,[82] the need for ground observers in an aircraft reporting service,[83] and how ground observation would help detect bombers.[84]

The advent of the GHQ Air Force resulted in an update to *TR 440-15*, now entitled *TR 440-15, Employment of the Air Forces of the Army,* dated 15 October 1935. It defined air operations as either independent air operations or those in conjunction with other forces, and defined anti-aircraft defense to include air forces, guns, searchlights, balloon barrage, and an aircraft warning service.[85]

While Air Forces could be assigned to GHQ AF, corps or armies, overseas departments, or to the zone of the interior, the commander in chief field forces “directs and controls the GHQ Air Force” by either assigning broad or general missions to the GHQ AF commander. The GHQ AF commander is responsible for selecting objectives and conducting air operations or assigning special missions. The GHQ AF commander is also responsible for conducting operations or assigning missions and supporting designated ground operations under direct control of the commander-in-chief fielded forces.[86] The result is that corps and army commanders still controlled air power.

Unintentionally, the Army Air Corps defined the need for an air command and control system, stating, “the operations of the constituent units of an air force must be closely coordinated. Such coordination assumes special importance when an air force is composed of more than one class of aviation and the missions of the various classes require them to operate at different times and places in the accomplishment of a common mission.” The air force must be prepared to deal with hostile air

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[82] ACTS Text, “Bombardment Aviation,” October 1933, ACTS, Maxwell Field AL, Call # 248.101-9, p. 133, in the USAF Collection, AFHRA, Maxwell AFB AL.
[83] ACTS Text, “Air Force-The Employment of Combat Aviation,” ACTS, Maxwell Field AL, 15 April 1937, Call # 248.101-7, p. 21, in the USAF Collection, AFHRA, Maxwell AFB AL.
[84] ACTS Text, “Bombardment Aviation” ACTS, Maxwell Field AL, February 1931, Call # 248.101-9, p. 120, USAF Collection, AFHRA, Maxwell AFB AL.
[85] War Department, *Training Regulations TR 440-15, Employment of the Air Forces of the Army* (Washington, 15 October 1935), Call # 107.108, in the USAF Collection, AFHRA, Maxwell AFB AL.
[86] Ibid.

at all time because constant air control is impossible. It reiterated the importance of a GHQ Air Force for rapid mobility. Additionally, air and ground forces were expected to closely coordinate to be effective, but this required a command and control system. Finally, the regulation discussed the Air Corps' role in the coastal defense mission.[87]

The Air Corps' primary role of defense and a War Department directive to conduct exercises with the Coastal Artillery Corps improved awareness to the need for an early warning network. The 1937-1938 ACTS Anti-aircraft Artillery text exposed students to sound locators, searchlights, and new methods of heat and radio detection. The text mentions a US patent dated November 27, 1934, called "A System for Detecting Objects by Radio," the principle being the detection of re-radiation from distant airplanes. The following is a quotation from the September 1935 issue of Klectronics, "Microwaves to detect aircraft, Telefunken firm in Berlin reveals details of ten centimeter 'mystery ray' system capable of locating position of aircraft through fog, smoke, and clouds. Rumors indicate the US and Italian armies are experimenting with similar systems, declared to revolutionize war tactics."[88]

The text also stressed, "A common command is necessary to provide for most efficient cooperation between the air fighting forces and the anti-aircraft artillery." It followed with, "the common commander of all active antiaircraft agencies in an antiaircraft defense area is the Antiaircraft Defense Commander, and he is charged with full responsibility for the antiaircraft defense of that specified area." The text concluded, "The aim in antiaircraft defense is to reduce the effectiveness of hostile air attack," causing aircraft to engage in defensive measures and minimize the probability of reattacks, thus making attacks less effective. AAA used in conjunction with either airborne or ground alert

[87] Ibid.
[88] ACTS Text, "Antiaircraft Defense," 1937-1938, ACTS, Maxwell Field AL, Call # 248.101-20, p. 41-437, in the USAF Collection, AFHRA, Maxwell AFB AL.

aircraft required a warning net or aircraft reporting service to be effective and maximize the engagement range.[89] A warning net made defense more effective because it did not require aircraft to stay airborne or know the enemy's objectives.[90]

The 1938 AAA text changed very little, but for the first time used the term "Aircraft Warning Service"[91] and "Aircraft Interception Net." The Aircraft Warning Service provided the detection service, conducted the intercept,[92] and manually plotted tracks based on ground observer reporting.[93] The 1938 Bombardment text also mentions the AWS for the first time, describing it as a required system to aid pursuit with interception, early warning, and tracking, coupled with methods to avoid enemy pursuit and AWS detection via routing, altitudes, and weather.[94]

As the concept of an aircraft warning net gained traction within the Corps, individual student research projects and continued ACTS involvement with field units to test their function and unit tactics, techniques and procedures began taking place. Captain Y. H. Taylor, an ACTS student from 1936-1937, discussed the importance of pursuit on alert, using an aircraft reporting net, and of controlling all operations via radio. He stated that pursuit for escort missions in both sweep and close escort roles made bombardment aircraft more effective. Pursuit "will be required to accompany and afford close protection to bombardment forces on all offensive missions." Touching on command and control, he

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89 ACTS Text, "Antiaircraft Defense," 1937-1938, ACTS, Maxwell Field AL, Call # 248.101-20, p. 3-4, 7, 12, 14-16, 21, 44, in the USAF Collection, AFHRA, Maxwell AFB AL.; ACTS Text, "Air Force-The Employment of Combat Aviation," 1 April 1939, ACTS, Maxwell Field AL, Call # 248.101-7, p. 3, 4, 6, in the USAF Collection, AFHRA, Maxwell AFB AL.

90 ACTS Text, "Air Force-The Employment of Combat Aviation," 1 April 1939, ACTS, Maxwell Field AL, Call # 248.101-7, p. 11, in the USAF Collection, AFHRA, Maxwell AFB AL.

91 ACTS Text, "Antiaircraft Defense," 1937-1938, ACTS, Maxwell Field AL, Call # 248.101-20, p. 30-31, in the USAF Collection, AFHRA, Maxwell AFB AL.

92 ACTS Text, "Antiaircraft Defense," 1937-1938, ACTS, Maxwell Field AL, Call # 248.101-20, p. 31-32, in the USAF Collection, AFHRA, Maxwell AFB AL.

93 ACTS Text, "Air Force-Antiaircraft Defense," 15 October 1938, ACTS, Maxwell Field AL, Call # 248.101-20, in the USAF Collection, AFHRA, Maxwell AFB AL.

94 ACTS Text, "Bombardment Aviation," January 1, 1938, ACTS, Maxwell Field AL, Call # 248.101-9, pp. 137-138, in the USAF Collection, AFHRA, Maxwell AFB AL.

concluded “Modern radio facilities, when used in alerting and controlling the action of fighting aircraft over friendly territory, creates an advantage to defending forces over attacking forces heretofore unknown in air warfare.” His instructor thought it a well-done project with ideas worth further consideration.[95]

In 1937, the ACTS attempted to create a practical pursuit problem for students using defensive pursuit aircraft with a simulated Aircraft Reporting Net. The school needed specific answers from the field to enhance training, including: whether or not units had an Aircraft Reporting Net in their area, how were they “navigated” by commands from their radio station, how did pursuit receive information from its Aircraft Warning Net, radio distance for control purposes, optimal intercept point, reaction time from alert, and aircraft type with capabilities.[96]

The response from the 8th Pursuit Squadron at Langley Field stated the ideal interception distance was 100 miles from the target, a number in line with Coastal Artillery texts from 1936. Effective radio range was only 40-50 miles, but lower frequencies extended the range. Command and control of the intercept took place from the Group radio station using plotting equipment and numerous personnel. These included the commanding officer, an enemy plotter, a friendly plotter to calculate intercept point, and another person to convert track information on a distance computer to determine magnetic heading. Yet another person used a second computer to correct airspeed based on altitude and temperature data and then type out a final message for a radio operator

[95] Individual Research, “Pursuit Aviation,” 1936-1937, by Captain Y. H. Taylor, ACTS, Maxwell Field, AL, Call # 248.282-11, in the USAF Collection, AFHRA, Maxwell AFB AL.
[96] Letter from ACTS, Maxwell Field, AL Pursuit Section, 8 April 1927, Operating Data, Call # 248.282, in the USAF Collection, AFHRA, Maxwell AFB AL.

to transmit to the aircraft. The 8th Pursuit Group standardized these processes in their *Operations Memorandum Number 6*, 18 March 1937.[97]

The First Pursuit Group at Mt Clemens, Michigan had similar data, although they viewed the maximum interception point at 30-40 miles, much closer to the target than the 8th Pursuit Group or Coast Artillery School solution. The shorter range of the P-26 versus the P-2 dictated the need to conduct intercepts closer to the aerodrome. Its radio range was approximately 50 miles and was commanded from the Group radio room. The simulated aircraft warning net transmitted the first enemy information at 80 miles, two operators plotted the course and altitude, and a radio operator in the plotting room received and sent the radio messages. The grid map, which all operators and pilots had a copy, used 10-mile concentric rings and 10-degree radial lines.[98]

On 11 April 1937, Headquarters 2d Wing, GHQ-AF at Langley Field issued *Operations Memorandum Number 1*. This memorandum provided guidance for an Assumed Air Intelligence Net for field exercises. The 20th Pursuit Group at Barksdale Field, LA responded with similar data and its own *Signal Operations Instruction*, dated 25 February 1937. It placed intercept range at around 60 miles (P-26A aircraft), radio range at approximately 60 miles, and control conducted from a Pursuit Group Defense Reporting Center. Unlike the 1st and 8th Pursuit Groups, the 20th employed not only ground observers for reporting, but also airborne scouts to extend detection range 100 miles from the scout's position.[99]

By the last year of the decade, views on pursuit began to change, so much so that "fighter aviation" became the recommended term instead

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97 Letter from 8th Pursuit Group, Langley Field, VA, 20 April 1927, Operating Data, Call # 248.282, in the USAF Collection, AFHRA, Maxwell AFB AL.
98 Letter from 1st Pursuit Group, Mt Clemens, Michigan, 29 April 1927, Operating Data, Call # 248.282, in the USAF Collection, AFHRA, Maxwell AFB AL.
99 Letter from 20th Pursuit Group, Barksdale Field, La, 29 April 1927, Operating Data, Call # 248.282, in the USAF Collection, AFHRA, Maxwell AFB AL.

of “pursuit.”[100] “In a similar vein, the term ‘Reconnaissance’ replaced ’observation’ because the latter was seen as too passive-sounding.”[101] The idea of the need for an aircraft warning service was firmly rooted and captured in an Air Corps Study entitled, *Study No.35 Part D, Pursuit Aviation*. It stated, “An aircraft interception net is vital to pursuit aviation in antiaircraft defense. A net can be best utilized by having the pursuit commander stationed at the central plotting board and directing pursuit operations by means of radio in accordance with the information received and plotted at these headquarters.”[102] It also recommended the network as part of an organized antiaircraft defense led by an antiaircraft defense commander with the appropriate command authorities.[103]

Rhetoric aside, bomber advocates stated the “Threat of pursuit is real and merits consideration.” Pursuit will reduce bombing effectiveness. If enemy pursuit is superior in performance, numbers and weapons, then “experience may prove escorting fighters essential if such situation arises. Escorting fighters will neither be provided nor requested unless experience proves that bombardment is unable to penetrate such resistance alone.”[104] Despite all the efforts to increase pursuit capability, a growing and capable early warning system, and tests showing bombardment’s vulnerability to pursuit operating under a well-developed and trained command and control system, bombardment advocates still thought bombers superior to pursuit. The 1938 Bombardment text stated, “The defenses against bombardment aviation are numerous, their powers real, but no matter how numerous or powerful they may be,

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[100] Letter to The Air Corps Board, Maxwell Field Alabama, “Study No. 35, Part D, Pursuit Aviation,” March 1, 1939, Call # 248.282-9, p. 4, in the USAF Collection, AFHRA, Maxwell AFB AL.
[101] Quoted from Dr. Richard Muller, 25 February 2014.
[102] Letter to The Air Corps Board, Maxwell Field Alabama, “Study No. 35, Part D, Pursuit Aviation,” March 1, 1939, Call # 248.282-9, p. 3, in the USAF Collection, AFHRA, Maxwell AFB AL.
[103] Letter to The Air Corps Board, Maxwell Field Alabama, “Study No. 35, Part D, Pursuit Aviation,” March 1, 1939, Call # 248.282-9, p. 3, in the USAF Collection, AFHRA, Maxwell AFB AL.
[104] ACTS Text, “Bombardment Aviation,” January 1, 1938, ACTS, Maxwell Field AL, Call # 248.101-9, pp. 141-142, in the USAF Collection, AFHRA, Maxwell AFB AL.

bombardment personnel will not be turned back nor pushed away from their assigned objective."[105]

Despite evidence from exercises and world events, (discussed later), the Air Corps exhibited and continued to exhibit cognitive dissonance until seeing the British command and control model in action and experiencing heavy bomber losses themselves in October 1943. The "Report of the Air Corps Board," 7 May 1939, for example, stated, "The availability of the best information of the enemy, which can possibly be provided by the aircraft warning service as an aid to effecting interception of the enemy aircraft, is essential to the successful employment of pursuit aircraft in antiaircraft defense."[106] In other words, with a warning net, pursuit can intercept enemy aircraft. Four sentences later the report states, "The higher operating speeds of modern bombers increases the difficulty of interception by hostile pursuit and thereby lessens the need of support by friendly pursuit."[107] The report claimed the near impossibility of ever building a fighter with the range of bombers, despite the Air Corps being aware of continuous experiments since 1925 regarding external fuel tanks. There were also continuing discussions in ACTS texts since at least 1929, and instructors at the ACTS, such as Captain Kenney suggesting them. Oddly, the same month as the release of "Report of the Air Corps Board," 7 May 1939, the Chief of the Air Corps directed "that no tactical plane be equipped with a droppable fuel tank."[108]

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[105] ACTS Text, "Bombardment Aviation," January 1, 1938, ACTS, Maxwell Field AL, Call # 248.101-9, p. 13, in the USAF Collection, AFHRA, Maxwell AFB AL.
[106] "Report of the Air Corps Board No 35, Employment of Aircraft in Defense of the Continental United States," 7 May 1939, Maxwell Field, AL, Call # 167.5-35, Annex 3, p. 4, in the USAF Collection, AFHRA, Maxwell AFB AL.
[107] "Report of the Air Corps Board No 35, Employment of Aircraft in Defense of the Continental United States," 7 May 1939, Maxwell Field, AL, Call # 167.5-35, Annex 3, p. 4, in the USAF Collection, AFHRA, Maxwell AFB AL.
[108] Bernard Boylan, *USAF Historical Studies: No. 136 Development of the Long-Range Escort Fighter*, USAF Historical Division Research Studies Institute (Air University, Maxwell AFB, Alabama, 1955), 44-46.; "Report of antiaircraft artillery--Air corps exercises in the vicinity of Fort Humphreys," September 14-24 1931, Call # 248.2124-11, in USAF Collection AFHRA, Maxwell AFB AL.

Most importantly, the Air Corps began to see the importance of command and control, at least for defensive purposes, even using the term "Command Control" when discussing various key elements stating,

> Suitable command control is essential to the effective coordination of pursuit aviation and AA artillery operating in the same area or in defense of the same installation or instrumentality. It is believed that the function of antiaircraft defense, within any given area, will be best performance when all elements of the defense force are under the direct control of a single defense commander"[109] and "that cooperation between pursuit aviation and AA Artillery, and the coordination of the operations of those two armies, can best be attained by unified tactical control in active antiaircraft defense operations, as developed in cooperative peace-time training."[110]

The confluence of multiple events led the Chief of the Air Corps to inquire as to the amount of pursuit training conducted at the ACTS. The ACTS Commandant responded to Brigadier General B.K. Yount, the Assistant Chief of the Air Corps, on 25 November 1939, in response to the Chief's inquiry about the school's pursuit curriculum and the proportion devoted to pursuit versus bombardment. Harmon responded, "Bombardment invincibility doctrine which reached its culmination a few years ago with its consequent influence on pursuit prestige irked me to no end; as did also the ill considered decision a few years ago to discontinue single-seater Pursuit bombing." Teaching pursuit reached an all time low from 1934-1936, with the school actually devoting fewer hours than prescribed in the official curriculum. The ratio at the end of 1939 stood at 5 to 3.8 for Bombardment over Pursuit. At the same time

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[109] "Report of the Air Corps Board No 35, Employment of Aircraft in Defense of the Continental United States," 7 May 1939, Maxwell Field, AL, Call # 167.5-35, Annex 3, p. 7, in the USAF Collection, AFHRA, Maxwell AFB AL.

[110] "Report of the Air Corps Board No 35, Employment of Aircraft in Defense of the Continental United States," 7 May 1939, Maxwell Field, AL, Call # 167.5-35, Annex 3, p. 4, in the USAF Collection, AFHRA, Maxwell AFB AL.

the school explored the theory of “Limited Aim,” which made enemy bombardment less effective by forcing it to take defensive measures against pursuit, believing the concept reduced bombardment effectiveness by 50%. They also covered “local” defense, bomber escort, patrols, and ground attack.[111]

In fact, the Pursuit Text, released in September 1939, now had a rather large section devoted to the aircraft interception net, interception techniques, “communication between a ground control center and aircraft,” plotting and data management, and night intercept. The text also highlighted the lack of any method to detect aircraft more than a few miles out.[112] Whether the ACTS knew of radar and kept it out of the texts due to secrecy or simply did not know is unknown. Nonetheless, the school now officially taught a concept of command and control at least for defensive pursuit.

By the end of 1939, General Arnold was clearly aware of the deficiencies in the Air Corps regarding pursuit aircraft, radar, AWS, air-ground coordination, and radios. Germany’s quick victory against Poland forced an evaluation of Air Corps thinking. “On 14 November 1939 Arnold stated that the doctrine so widely propounded in Air Corps circles for so many years to the effect that fighter aircraft could not shoot down large bombardment aircraft flying in defensive formations had been ’proven wholly untenable.’”[113] Asked whether the United States should produce existing early warning radars or delay production in the expectation of getting improved microwave equipment, he stated the Air Corps "was badly in need of detector equipment for tactical use" and required equipment immediately for training purposes, even if it was not

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[111] Letter from Col M. F. Harmon, ACTS Maxwell Field, AL to Brigadier General B. K. Yount, November 25, 1939, Call # 145.91-563, in the USAF Collection, AFHRA, Maxwell AFB AL.
[112] ACTS Text, “Pursuit Aviation,” September 1939, ACTS, Maxwell Field AL, p. 70-102, Call # 248.101-8, in the USAF Collection, AFHRA, Maxwell AFB AL.
[113] Futrell, *Ideas, Concepts, Doctrine* 96.

the ultimate type produced.[114] Arnold may well have been thinking about the new capabilities of electronic-directed pursuit when he wrote, "During daylight in good weather, when pursuit aviation is present in strength in an area, it can pretty nearly bar the air to the bomber."[115] Arnold was also aware “the British had developed a system of electronic early warning and fighter control without which the Royal Air Force Fighter Command probably could not have defeated the Luftwaffe during the Battle of Britain.”[116]

Air-to-Ground Operations

From 1939 to 1941, the Army began preparations for combat. The Air Corps however, did not provide many aircraft, but it did devote a bomber wing for air support tests with the Army that took place from February to June 1941. During these tests, they developed the basic communication processes for air-ground cooperation, the minimum safe distance for bombing near ground troops, and other procedures. The main reason for the limited Air Corps Support was the massive increase in size of the Air Corps between 1939 and 1941.[117]

By the end of 1941, the Air Corps became more involved as the expansion now made it possible to participate. The Louisiana Maneuvers, one of the largest and most complex air-ground exercises, occurred in September 1941. Overall, air power and the support to ground forces went well. The Air Corps learned some valuable lessons. The maneuvers highlighted that ground units still did not have a method to indicate their position to aircraft. It did however, validate the concept of centralizing airpower under a single commander, and the basic processes of the air support command concept worked despite acknowledgement it still had problems. For example, the time from an air request to support took

[114] Ibid, 101.
[115] Ibid, 101.
[116] Ibid, 99.
[117] Christopher R. Gabel, *The U.S. Army GHQ Maneuvers of 1941* (Washington, D.C.: Center of Military History, U.S. Army, 1992), 40-41

approximately one hour and twenty minutes. Overall, the Army considered the maneuvers a success as processes improved and lessons were drawn.[118]

For the Carolina Maneuvers, held October to November 1941, "the Army Air Forces officially implemented the air support command concept, but with an increased emphasis on the centralization of air assets." During these maneuvers the Air Corps used the Air Support Command concept, focused on interdiction missions, and held to the idea that airpower should not be used near forces within artillery range unless necessary. Air-ground cooperation improved from the Louisiana Maneuvers. The experience from the Louisiana and Carolina Maneuvers was captured in the April 1942 release of *FM 31-35, Aviation in Support of Ground Forces*.[119]

Maneuvers continued throughout 1942 and 1943 from which the Army and Air Corps drew lessons. During an October 1942 maneuver at Camp Young, California, the Air Corps called for all ASC and ASP to have standardized equipment and a standard composition to include the Control Officer, A-2 Representative, Bombardment Representative, Observation Liaison, and Communications Officer. The "Report of Signal Communication" from the maneuver, discussed the need for standard radio sets, the correct number of communications personnel, and the use of radio sets on tracked vehicles to improve mobility. The Forty-Sixth Bombardment Group thought radio employment could be improved and that they were still learning how to conduct air support operations. The Group worked on using panels and lights to guide attacks and used lights, smoke, panels, and paint to identify the location of ground troops.[120]

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[118] Ibid, 119-120.
[119] Ibid, 179-180.
[120] Report. "Lessons and Recommendations Based on Air-Ground Operations at Desert Training Center Maneuvers, 1942," Headquarters, Desert Training Center, Camp Young California, October 22, 1942, pp. 1-2, Call # 245.31-1 V.20, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report. "Report

Thoughts from the Field

Immediately after WWI, the Army continued focusing on defending against enemy aircraft. No system or capability existed to prevent all enemy aircraft from attacking protected areas; yet, an effective barrier could inflict and disrupt observation and bombing efforts.[121] The Army recognized airpower's mobility and the possibility of moving beyond concepts of point defense to area defense to protect large areas.[122] This was of particular interest due the size of the U.S. and high aircraft costs, which precluded large purchases, especially in the post war economic environment.

German attacks against Paris in 1918 demonstrated the effectiveness of an integrated air defense system and the underlying command and control system. Germany flew 483 sorties against Paris, but only 37 flew over the city and 13 of those were shot down. The French estimated these aircraft dropped 11,680 kg of explosives over a year period, yet the Germans claimed they dropped 22,000 kg on a single night in September 1918. The French determined that many German aircraft never dropped their bombs on the intended targets and simply released their bombs on less defended areas.[123] The US Army had its own data demonstrating the effectiveness of both AAA and aircraft for defense. The Aviation Services accounted for four-fifths versus the one-fifth of airplanes destroyed by AAA.[124]

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of Signals Communications, Air Support Command," Headquarters, Desert Training Center, Camp Young California, October 10, 1942, Call # 245.31-1 V.20, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report. "Desert Training Maneuver Report," Headquarters, Forty-Sixth Bombardment Group (L), Blythe Army Air Base, Blythe, California, 19 Oct 1942, Call # 245.31-1 V.20, in the USAF Collection, AFHRA, Maxwell AFB AL.;

[121] Thomas R. Phillips, Captain, "Some Phases of the Effect of Aircraft on the Future Mission, Organization, Equipment and Tactics of the Coast Artillery Corps," *Coast Artillery Journal* (March 1923): 210-211.; Benjamin F. Harmon, Captain, "The Mission and Tactics of Antiaircraft Defense," *Coast Artillery Journal* (September, 1923): 236.

[122] C. L'H. Ruggles, Brigadier General, "Antiaircraft Defense," *Coast Artillery Journal* (March, 1926): 223.

[123] J.C. Haw, Major, "Antiaircraft Defense," *Coast Artillery Journal* (October, 1925): 328.

[124] C. L'H. Ruggles, Brigadier General, "Antiaircraft Defense," *Coast Artillery Journal* (March, 1926): 226.

Nation	Planes brought down by Aviation Service	Planes brought down by A. A. guns
Italy	540	129
Germany	6554	1520
France	2000	500
	9091	2149

Table: 6[125]

Within this context, technological advances coupled with defensive and joint operational thought, flourished in the 1920s to solve various problems. Many of the issues contributing to the development of a command and control system took place within the Coast Artillery Corps and Air Service/Air Corps, mostly in a spirit of cooperation. Although cooperation prevailed, there were professional discussions refuting the "propaganda" of the air service, mainly the idea airplanes could replace all other weapons, the bomber could get through and survive against heavy defenses, and win wars on its own.[126]

Navy and Army personnel, including Air Service officers, advocated close cooperation, the need for battleships, and the idea infantry wins wars, but generally the discussions leaned toward creating a balanced force.[127] Despite these differences, the overall tone of the dialogue was civil and balanced.[128] *Coast Artillery Journal* editors fostered this environment, publically welcoming Air Service articles and dissenting opinions,[129] creating an important venue for the development of doctrine, tactics, techniques and procedures related to command and control. While cooperative thought prevailed, it may have been pragmatic as the CAC realized it needed airpower to fulfill its mission. The CAC saw RAF

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125 Ibid, 225.
126 J. T. McNarney, Major, "The Influence of Air Power on Coast Defense," *Coast Artillery Journal* (October, 1925): 330.
127 H. J. Hatch, Colonel and J. F. Stiley, Captain, "Coast Defense-Logical and Visionary," *Coast Artillery Journal* (January, 1924): 1.
128 H. C. Barnes, "Present and Prospective Development of Antiaircraft Artillery and its Probable Effect upon bombing Operations," *Coast Artillery Journal* (April, 1924): 255.
129 McNarney, "The Influence of Air Power on Coast Defense," 329.

independence across the Atlantic and its apparent moves to provide less support to the Army (Coast Artillery) as a threat to its own mission.[130]

All branches recognized pursuit's primary role of gaining air superiority. While agreeing on the necessity and primary mission of gaining control of the air, the Navy questioned airpower's role in coastal defense. Mirroring the thoughts of the Morrow Board, the Army and Navy did not think American cities were at risk from air attack. Nonetheless, airmen enthusiastically embraced the air defense mission; in the post war environment it was a raison d'etre.[131]

Synthesis and cooperation between branches began early, due to individual initiative and direction from higher headquarters. On March 24, 1922, the Adjutant General of the Army directed the Air Service and Coastal Artillery to create a joint training program, determine limitations and capabilities, how to use of aircraft to conduct fires, how to control fires beyond visual range of shore, how to use searchlights, and to develop an information service. The same directive charged the Chief of the Air Service to conduct exercises to demonstrate independent air missions for coastal defense.[132]

Almost immediately, the question of who should command Air Defense units came to the fore, but unity of command was the one constant; Air Defense units should be centralized in the "Defense Commander's Station,"[133] because aircraft should not be frittered away.[134] Unsurprisingly, those in the Coastal Artillery Corps recommended they command the defense, placed under the Corps

[130] F. W. Barron, Lieutenant Colonel, "Duncan Gold Medal Essay, 1921-22," *Coast Artillery Journal* (November 1922): 460.
[131] Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941*, 31.
[132] "Coast Artillery-Air Service Training," *Coast Artillery Journal* (July, 1922): 68.
[133] Benjamin F. Harmon, Captain, "The Archies and the Antiaircraft Service," *Coast Artillery Journal* (June, 1922): 548.
[134] J.C. Haw, Major, "Antiaircraft Defense," *Coast Artillery Journal* (October, 1925): 318.

Commanders.[135] Air Service opinions are glaringly absent on this issue throughout the 1920s in a journal that discussed so many other issues requiring coastal artillery and air cooperation.

Regardless of the command relationships between the two arms, the Army continually stressed cooperation between land and air forces; combined arms were viewed as most effective,[136] best expressed with the statement, "the lessons of this new offensive weapon [aircraft] is a repetition of the lessons learned from each new weapon development—that of combined arms."[137] *TR 435-44, Combined Training of Coast Artillery and Air Corps, 1929* finally formalized this relationship, emphasizing integrated communications, the use of devices to locate the enemy, and working together to increase the probability of success.[138]

With aircraft and AAA available for defense, the problem became one of how to concentrate quickly a sufficient number of aircraft to gain supremacy when and where needed. The solution was to create a warning system to pass information to not only AAA batteries, but also aircraft; by mid-decade, an early warning system was a requirement for anti-aircraft defense.[139] Providing timely warning of enemy aircraft to defending aircraft[140] became the principal function of the anti-aircraft

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[135] H. R. Oldfield, Major, "Organization of Ground Means of Antiaircraft Defense," *Coast Artillery Journal* (April, 1925): 284-296.; Benjamin F. Harmon, Captain, "The Archies and the Antiaircraft Service," *Coast Artillery Journal* (June, 1922): 528.

[136] Benjamin F. Harmon, Captain, "The Archies and the Antiaircraft Service," *Coast Artillery Journal* (June, 1922): 539.; Thomas R. Phillips, Captain, "Some Phases of the Effect of Aircraft on the Future Mission, Organization, Equipment and Tactics of the Coast Artillery Corps," *Coast Artillery Journal* (March, 1923): 224.; "Air Service and Coast Artillery Cooperation," *Coast Artillery Journal* (April, 1922): 463.; "Harmony in Anti-Aircraft Doctrine," *Coast Artillery Journal* (June, 1922): 563-564.; Benjamin F. Harmon, Captain, "The Mission and Tactics of Antiaircraft Defense," *Coast Artillery Journal* (September, 1923): 233-234.

[137] Thomas R. Phillips, Captain, "Some Phases of the Effect of Aircraft on the Future Mission, Organization, Equipment and Tactics of the Coast Artillery Corps," *Coast Artillery Journal* (March, 1923): 224.

[138] *Training Regulation No. 435-44, Combined Training of Coast Artillery and Air Corps*, War Department, Washington, 1929, Call # 248.2124-9, in the USAF Collection, AFHRA, Maxwell AFB AL.

[139] H. R. Oldfield, Major, "Organization of Ground Means of Antiaircraft Defense," *Coast Artillery Journal* (April, 1925): 282.

[140] C. L'H. Ruggles, Brigadier General, "Antiaircraft Defense," *Coast Artillery Journal* (March, 1926): 224.

service.[141] An early warning system to provide situational awareness on enemy aerial activity required an effective organization structure.[142] A process evolved within the anti-aircraft surveillance system to assist with aircraft warning and passing information to aircraft. The system used ground observers, manned balloons at 4,000 ft (with accurate observation out to 20,000 yards), and a listening service of specially trained men to differentiate the sound of various aircraft. It also tracked aircraft and coordinated with the air service. Sector observers used radios and landlines to pass carefully recorded information on enemy aircraft activity to the Air Service.[143] Armed with information, aircraft took off and attacked incoming aircraft. At night, the system relied on AAA and machine guns.[144] The warning system worked, but was labor and communications intensive.[145] This criticism continued to be valid through the 1930s.

The growing complexity of modern communications on the battlefield after WWI led the Signal Corps to create a Message Center as part of a communications system to centralize information and improve efficiency. A training regulation described how to manage the massive quantities of data coming into various headquarters of combat units.[146] The Signal Corps knew the importance of a single unified net, properly

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[141] Thomas R. Phillips, Captain, "Some Phases of the Effect of Aircraft on the Future Mission, Organization, Equipment and Tactics of the Coast Artillery Corps," *Coast Artillery Journal* (March, 1923): 224.
[142] H. R. Oldfield, Major, "Organization of Ground Means of Antiaircraft Defense," *Coast Artillery Journal* (April, 1925): 287.; Thomas R. Phillips, Captain, "Some Phases of the Effect of Aircraft on the Future Mission, Organization, Equipment and Tactics of the Coast Artillery Corps," *Coast Artillery Journal* (March, 1923): 213.
[143] Benjamin F. Harmon, Captain, "The Mission and Tactics of Antiaircraft Defense," *Coast Artillery Journal* (September, 1923): 235.; H. R. Oldfield, Major, "Organization of Ground Means of Antiaircraft Defense," *Coast Artillery Journal* (April, 1925): 282.; Benjamin F. Harmon, Captain, "The Archies and the Antiaircraft Service," *Coast Artillery Journal* (June, 1922): 539, 545.; William T. Carpenter, Major, "The Influence of Aviation upon Coast Defense," *Coast Artillery Journal* (May, 1926): 471.
[144] Benjamin F. Harmon, Captain, "The Archies and the Antiaircraft Service," *Coast Artillery Journal* (June, 1922): 542.
[145] H. R. Oldfield, Major, "Organization of Ground Means of Antiaircraft Defense," *Coast Artillery Journal* (April, 1925): 287.
[146] *Signal Corps Bulletin,* No 3, August 1, 1920.

planned to tie in all aspects of the network, including frequency deconfliction. It fought back against any effort to have individual communications networks.[147] Developments such as these continued to contribute to the evolution of a command and control system and helped manage the growing amounts of data flowing into command centers.

By the early 1930s, several well-established concepts existed. The first was the need for a warning and intelligence network coupled with AAA to reduce bombing's effectiveness.[148] Second, the most effective system of defense required a single commander to coordinate the effects of aircraft, AAA, lights, communications, and intelligence. Third, effective communications to deliver the information when and where needed required a robust radio system. Finally, intercepting aircraft required sufficient early warning.[149]

Captain Kenneth Walker, writing in 1930 in the *Coast Artillery Journal* stated, "When a bombardment unit clears its airdromes with a mission of destroying a vital objective deep within a hostile territory, it will be opposed vigorously by the enemy's defense forces; the hostile pursuit aviation and antiaircraft artillery."[150] He and the Air Corps were well aware pursuit would attempt to intercept bombardment aircraft and escorting pursuit could protect the bombers.[151] It had occurred during the Great War and exercises had already shown this to be the case. The

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[147] *Signal Corps Bulletin*, No 68, September-October 1932, 20.

[148] P. P. Bishop, Colonel, "The Effect of Aviation upon the Mission of the Coast Artillery," *Coast Artillery Journal* (February, 1931): 93.; "The Sole Role of Antiaircraft Artillery in Air Defense," *Coast Artillery Journal* (June, 1930): 498.

[149] P. P. Bishop, Colonel, "The Effect of Aviation upon the Mission of the Coast Artillery," *Coast Artillery Journal* (February, 1931): 96.; Joseph C. Haw, Major, "Lessons of the German Air Raids on Great Britain During the World War," *Coast Artillery Journal* (July-august 1932): 253.; Edward W. Timberlake, Captain, "The Effect of Antiaircraft Artillery on the Employment of Aviation," *Coast Artillery Journal* (May-June, 1932): 178.; Fred G. Borden, Captain, "Communications to and From Airplanes in Flight," *Coast Artillery Journal* (March, 1930): 213.; "The Sole Role of Antiaircraft Artillery in Air Defense," *Coast Artillery Journal* (June, 1930): 498.; *Signal Corps Bulletin*, No 68, September-October 1932, 19.

[150] K. N. Walker, 1st Lieutenant, "Driving Home the Bombardment Attack," *Coast Artillery Journal* (October, 1930): 328.

[151] Ibid, 333, 338.

Army, outside the Air Corps, no longer questioned this idea, rather focusing on how to improve early warning and integrate pursuit and AAA. Many in the Air Corps appeared focused on getting a bomber that made all these discussions and exercises moot.

The CAC however continued to embrace fully the idea of a warning net. In its 1936 school texts the Coast Artillery called the ground observer and communication system of any metropolitan area the "soul of the air defense," and that "the primary objective of the observation and command communications systems is to enable the friendly pursuit formations promptly to make contact with and attack the hostile air formations before they reach the gun defense area." Extending the warning system far enough away from the defended node to provide pursuit aircraft enough time to make the intercept or employing defensive observation aviation to observe enemy airdromes or follow bombers and report their location to defensive pursuit accomplished this objective.[152]

In 1936 Captain Parker, an ACTS instructor, asked Major Bissell, now stationed at Hickam, for his thoughts on pursuit. Major Bissell believed bombers were superior to pursuit due to pursuit's outdated aircraft and equipment. The major problems dealing with defense included geography, the range of bombers, and lack of gun mobility. He did not think listening devices, nor the labor- and material- intensive communications networks used in previous years' exercises, to be effective. In his estimation, unless pursuit had a 40-50% speed advantage over bombers, there was no way to protect specific points.[153] His suggestion for improving pursuit's performance over bombers

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[152] Lecture "Air Defense of a City," Department of Tactics, Coast Artillery School, 1936, Call # 248.282-18, in the USAF Collection, AFHRA, Maxwell AFB AL.; H. A. Dargue, Major, "Bombardment Aviation and its Relation to Antiaircraft Defense," *Signal Corps Bulletin*, *No 84* (May-June 1935): 29.; Fred G. Borden, Captain, "Signal Communication for an Air Force," *Signal Corps Bulletin*, *No 68* (September-October 1932): 20.

[153] Letter from Major Bissell to Captain Parker, ACTS, Maxwell Field, September 8, 1936, Call # 248.82-20, in the USAF Collection, AFHRA, Maxwell AFB AL.

focused on aircraft rather than other external technology or processes. This single-minded approach dominated Air Corps thought, with only a few advocating otherwise.

Despite the bomber's ascendancy over pursuit, those in other arms of the Army and some airmen did not let bombardment's technological and doctrinal rise deter them from either advocating or innovating. For example, artillery officers continued to discuss the importance of combined action by AAA and pursuit aircraft and the importance of information nets, including ground observers.[154] Many Air Corps officers agreed with the artillery officers. The HQ 1st Pursuit Group at Selfridge Field created the first-ever "Air Command Section" to control the group in flight, receive and evaluate information on enemy aircraft from its Aircraft Warning Service, and control aircraft to an intercept.[155]

Other innovations continued increasing the Air Corps' command and control capabilities. In 1939, Major George C. Kenney, then Commanding the 97th Observation Squadron at Mitchel Field, L.I., New York, introduced an air to ground signal method to speed up the communications process between air and ground units. His unit tested the procedures with various ground units. The procedure used flags and reduced the message system staffing from six or eight men to just two. This process was simpler than the one requiring the pilot to find a ground panel, receive the message, and then drop the written answer at the panel station. It added flexibility, removing the need for troops to find clearings, raise hooks, etc. The flag system allowed message transmission at any time and from anywhere, even moving vehicles. These procedures were disseminated throughout the Army.[156]

[154] Robert N. Mackin, Major, "Airplanes Can be Stopped," *Coast Artillery Journal* (September-October, 1937): 397, 400.
[155] *Air Crops Newsletter*, V8074 A.C., 1 June 1939.
[156] *Air Crops Newsletter,* V7967 A.C., 1 February 1939.

Exercises and Maneuvers

Exercises and maneuvers served as excellent venues to test tactics and technology, train, conduct joint operations, and demonstrate the growth of command and control concepts.

Exercises in the 1920s were progressive. The 1925 exercise at Mitchell Field and Langley simulated an attack on the Atlantic coast, the 1926 maneuvers at Wright Field dealt with the concentration of forces prior to an opening battle, while the 1927 exercise trained staffs on the initial contact.[157] In 1928, the Air Corps used all aircraft classes to demonstrate their use and integration with ground forces. In 1929, the objective was to concentrate, approach, contact, and focus on the initial battles.[158]

The 1925 maneuvers concluded the need for "a network of radio stations with directional wireless," recommending aircraft engaged in coastal defense check in to stations built along the coast. Checking in to these stations helped ground plotters track aircraft position on their plotting tables.[159] The 1926 maneuvers addressed pursuit protection of bombardment due to the inadequate performance and protection capabilities of bombardment aircraft. During the exercise, defensive pursuit intercepted bombardment aircraft with assistance from an observation net. The Air Service concluded, "unless we have a preponderance of Pursuit, the line of objectives of day Bombardment should not be deeper than the line of interception by alerted enemy Pursuit." Phrased more simply, bombardment needed pursuit to survive. Conversely, night bombardment was effective due to pursuit's inability to operate at night. Indicating the state of the Army's communications at

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157 Letter from Assistant Chief of Air Corps to Adjutant General regarding Maneuvers of the Army Air Service, May 17, 1926, Call # 248.2122, in USAF Collection AFHRA, Maxwell AFB AL.

158 Russian translation, "The air-ground maneuvers of the Air Corps of the U.S. Army, Fifth Corps area," Columbus Ohio, May 12-26, 1929, Call # 248.2122, in USAF Collection AFHRA, Maxwell AFB AL.

159 Report "Air Force Maneuvers, October, 1925," December 1, 1925, Call # 248.2122, in the USAF Collection, AFHRA, Maxwell AFB AL.

the time, the Army used commercial nets during the exercise. Finally, the report recommended the 1927 maneuvers continue using radios for all aviation missions.[160]

Despite improved radio performance, the Air Corps' use of the technology did not improve in 1928. The report for the Field Exercises at Virginia Beach concluded the Air Corps was not keeping up with advances in radio technology. Reliable two-way radio was available and achievable with current equipment and methods, requiring only proper planning and training.[161] The Air Corps improved its radio integration and use during the 1929 air-ground maneuvers.

At the conclusion of the 1929 air-ground maneuvers, the Secretary of War highlighted the great air-ground cooperation, the importance of air as the eyes of the army, and the swiftness of reports provided to ground units. The report also noted the inability to intercept aircraft and the need for a system to find and identify aircraft in order to facilitate intercepts.[162] Despite the Secretary of War's comments highlighting the need to identify and intercept aircraft, Major Walter H. Frank, assistant commandant of the Air Corps Tactical School and the chief umpire, stated at the end of the exercise, "There is considerable doubt among the umpires as to the ability of any air organization to stop a well organized, well flown air force attack….The difficulty that pursuit had, not only in attacking, but in finding some of the missions that were sent in to hostile territory during these maneuvers, would make it appear that a well planned air force attack is going to be successful most of the time." Rather than address whether to develop a system to identify and assist in destroying incoming bombers, Air Corps leaders merely reemphasized

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[160] Letter from Assistant Chief of Air Corps to Adjutant General regarding Maneuvers of the Army Air Service, May 17, 1926, Call # 248.2122, in USAF Collection AFHRA, Maxwell AFB AL.
[161] Report "Virginia Beach Maneuvers, General Recommendations," May 18-20, 1928, Call # 248.2122, in USAF Collection AFHRA, Maxwell AFB AL.
[162] Russian translation, "The air-ground maneuvers of the Air Corps of the U.S. Army, Fifth Corps area," Columbus Ohio, May 12-26, 1929, Call # 248.2122, in USAF Collection AFHRA, Maxwell AFB AL.

deeply held beliefs.[163]

Early warning and command and control concepts slowly gained traction in the 1930s. AAA units developed specific intelligence batteries dedicated to identifying an enemy early enough for AAA guns and aircraft to be effective. Testing the air defense intelligence network, with the Air Corps, Coast Artillery Corps, and Antiaircraft Brigade Intelligence Battery all participating, was the primary objective of the Joint Antiaircraft Artillery-Air Corps exercises held at Aberdeen, May 12-17, 1930.[164]

The exercise used an early warning system comprised of observation posts in three belts of 45, 70, and 100 miles centered on Aberdeen with posts within each ring separated by 5 miles. Ground observers reported enemy aircraft activity via radio and landline between each other and to the intelligence center. Any other ground units identifying enemy aircraft reported the information to the intelligence center.[165] The outer 100-mile ring became a standard based on aircraft performance to ensure sufficient time for interception.

Various phases of the exercise had multiple objectives, almost all focused on issues of command and control such as testing the function of the observation network, the organization of the intelligence center and defense headquarters, communication and information flow, how to get intelligence to airborne pursuit, and other command functions. The exercise planning board considered an Air Corps officer in command of the defense to be a natural condition where the defended locality happened to be an airdrome.[166]

The Intelligence Center of the AAA Battery was collocated with Defense Headquarters. As information arrived, tracks were plotted based on incoming reports from observation posts. Both AAA units and pursuit

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[163] Futrell, *Ideas, Concepts, Doctrine*, 64.
[164] "Joint Antiaircraft-Air Corps Exercises at Aberdeen Proving Ground," *Coast Artillery Journal* (May, 1930): 404.
[165] Ibid, 404.
[166] Ibid, 406-408.

units received the plotted information, but tracking became difficult if bombers flew irregular paths. Scale on a map determined aircraft speed. With timely information, the Defense Commander had sufficient time to intercept enemy flights, leading to mostly successful intercepts. At the exercise's conclusion, participants compared the plotted path to the actual enemy flight path to test the system's accuracy. Overall, the system proved successful, but labor intensive; 95 men in the field with varying levels of support up to an additional 220 men. During night operations, observers had little difficulty identifying aircraft with searchlights despite lacking listening devices. Pursuit aircraft did not participate at night during this exercise.[167]

The exercise centered on communicating, discovering enemy aircraft, and transmitting information to the right people for action. The concluding report found radio communication between the Defense Headquarters and the pursuit leader satisfactory on nearly all flights, but that the Signal Corps should continue developing a light, portable, and efficient short wave unit since its current radios lacked power, were bulky, and difficult to use. It also suggested formally integrating the experimental AAA Intelligence into the AAA unit.[168]

The 1930 Air Corps Field Exercises focused on training tactical units, noting the successful interception of low flying bombardment and attack aircraft. Aircraft radio employment for rendezvous and air ground coordination were good and increased the "ease and flexibility of command," making changing objectives in flight possible. Radio made intercepts, rendezvous, and the control of airborne units possible. The Air Corps experimented with controlling an entire pursuit squadron via radio. It concluded that the early warning system providing information

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[167] C. E. Atkins, Captain, "Joint Antiaircraft Air Corps Exercises, Aberdeen Proving Ground, Maryland, May 12-17, 1930," *Coast Artillery Journal* (October, 1930): 319-324.
[168] Atkins, "Joint Antiaircraft Air Corps Exercises, Aberdeen Proving Ground, Maryland, May 12-17, 1930," 321-326.

on enemy activity via radio every ten miles made the intercepts possible.[169]

The Ft Humphrey AAA-AC Maneuvers held September 14-24, 1931, tested AAA searchlights and sound locaters, highlighting the effectiveness of sound locators and the desirability of pursuit working with AAA and searchlights. Once again, two-way communication between pursuit and AAA proved necessary. Testing beacons at aerodromes and utilizing a second location to triangulate a target also occurred. The author of the report, Captain George C. Kenney, made numerous recommendations including the need for aircraft engine silencers, infrared detectors, and rocket engines. He attacked the Air Corps' argument that no nation will have enough AAA to defend every possible target, the Air Corps' poor performance at the exercise, the Air Corps getting all the equipment, and the Air Corps' answer of using many bombers to overwhelm the enemy's defense (defending pursuit and AAA) thus reducing its own casualties. He concluded, "it is urged that the above not be considered merely as an alarmist report, but that the recommendations and conclusion contained herein be analyzed with a view to putting the Air Corps in position to carry out the mission which has been assigned to it. The tactical problems of the Air Corps can all be solved, but not with our present equipment nor according to many of our existing tactical doctrines."[170]

Reflecting the rise of bombardment and the growing antagonism between bombardment and other aviation such as pursuit (Kenney served as an Attack Aviation instructor at the ACTS), Captain Kenneth Walker formally refuted various points of Kenney's report. He noted the ACTS does in fact teach AAA is dangerous to bombardment aircraft

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[169] "Report on Air Corps Field Exercises and Demonstrations 1930," Call #248.2122-1, in USAF Collection AFHRA, Maxwell AFB AL.
[170] "Report of antiaircraft artillery--Air corps exercises in the vicinity of Fort Humphreys," September 14-24 1931, Call # 248.2124-11, in USAF Collection AFHRA, Maxwell AFB AL.

despite many officers in the Air Corps believing otherwise. The school also emphasized units in defensive formation will never attack known AAA defenses and that the current doctrines taught should be field-tested.[171] Countering Keeney's comments regarding the amount of equipment the Air Corps received, Walker stated,

> If we commit ourselves to passive defense or if an enemy does the same we or he will find that a great proportion of the resources will be devoted to antiaircraft and pursuit and necessarily, the amount of our truly offensive aviation-bombardment and attack may suffer. If, on the other hand, we commit ourselves to the time-honored and proven policy that offense is the best defense we won't nor will the enemy have the vast amount of defensive material which is so freely talked about. This the belligerent which can hit the hardest while accepting the attacks of the enemy will be the one which is successful in war. Hence a question arises as to whether or not the enemy will ever have enough antiaircraft material to defend strongly and successfully those objectives against which bombardment units will be sent if he follows sound principles of warfare.[172]

Unintentionally, Walker's counter arguments get at the heart of the debates between pursuit and bombardment. Not only did each side passionately believe in their position, but it was also about money, especially in a fiscally constrained environment. The same thought process of where to spend money is potentially why the Air Corps neglected command and control. The Air Corps was not willing to spend limited resources on radio and detection device development when the main mission was flying. Even with aircraft, the Air Corps neglected all aviation classes except bombardment until the late 1930s. Only money

[171] Ibid.
[172] Ibid.

for experimental fighter aircraft kept technology advancing and aircraft companies in business.

Coastal defense without the US fleet available and combat "against a land-based enemy air force" were the scenarios in the March Field exercises held in 1933.[173] Bombardment aircraft provided defending pursuit their position to simulate an early warning net and test pursuit's ability to stop bombardment. Reciprocally, the exercise also tested bombardment's ability to successfully attack against defensive pursuit. The exercise purposely ensured pursuit aircraft knew the attacking bomber's positions.[174] As a result, Lt Col John D. Reardon on the Air Corps staff wrote three months later, "it [simulated intelligence and warning net] left a gap in the conclusions drawn as to the possibilities of securing sufficient information that requires us to look to a subsequent air force maneuver to fill." He made these comments despite the well-publicized conclusions of the almost concurrently executed Ft Knox exercise. When pursuit intercepted bombardment after dropping on the target, he brushed away the successful intercept and when a second group was intercepted before hitting its target, it too was brushed away with the comment, "It could, therefore, have bombed any one of several objectives in the area penetrated. The fact that this attack did not reach San Bernardino, therefore, does not mean that the defense was successful." Lt Col Reardon applied a 100% intercept standard to prove the worth of an air-warning network, despite admitting the intercept lines were too close to give the system time to alert aircraft, launch them, and fly to the intercept point. Finally, both attackers' and defenders' radios functioned well enough to assemble aircraft and control them in

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[173] John D. Reardon, Lieutenant Colonel, "Air Maneuvers on the West Coast," *Coast Artillery Journal* (September-October, 1933): 355.
[174] Letter "Employment of Tactical Units Equipped with Modern Pursuit and Bombardment Airplanes," November 26, 1934, by Lt Col HH Arnold to the Chief of the Air Corps, Call # 248.282-15, p. 3, in the USAF Collection, AFHREA, Maxwell AFB AL.; John D. Reardon, Lieutenant Colonel, "Air Maneuvers on the West Coast," *Coast Artillery Journal* (September-October, 1933): 355.

the air.[175] Nonetheless, the final report concluded the need to command and control from the air, recommending the development of a specific command aircraft.[176]

Almost mirroring British air power thought, the GHQ Air Force Command and Staff Exercise Report of 1933 concluded,

> Since new bombardment aircraft possesses speed above two hundred miles per hour, any intercepting or supporting aircraft must possess greater speed characteristics if they are to perform their mission. In the case of pursuit aviation, this increase of speed must be so great as to make it doubtful whether pursuit aircraft can be efficiently or safely operated either individually or in mass……The modern trend of that is that high speed and otherwise high performing bombardment aircraft, together with observation aviation of superior speed and range and communications characteristics, will suffice for the adequate air defense of this country.[177]

A letter to the Chief of the Air Corps from Lt Col H. H. Arnold entitled, "Employment of Tactical Units Equipped with Modern Pursuit and Bombardment Aviation," also contained several contradictory statements regarding a warning system's effectiveness. It highlighted several items including the absolute need of frequent and accurate reports from ground observers to ensure interception. The report also cited single seat pursuit aircraft as ineffective, "as dead as the gladiator or armored knight," and a waste when escorting bombers to target, but found multi-seat pursuit could be used to clear enemy pursuit for the bombers. "Against multi-seater fighters, it is believed that there is no adequate protection except that furnished by supporting multi-seaters, this being based on experience gained in recent practices at this station."

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[175] John D. Reardon, Lieutenant Colonel, "Air Maneuvers on the West Coast," *Coast Artillery Journal* (September-October, 1933): 355, 357, 359
[176] Report, "GHQ Air Force Command and Staff Exercise 1933," Call # 248.2122-3, p. 13, in USAF Collection, AFHRA, Maxwell AFB AL.
[177] Ibid, 12.

It also concluded enemy pursuit would be required to engage the pursuit first before engaging the bomber formations when pursuit aircraft were near the bombers. Thus, pursuit "would have accomplished our mission of protecting our Bombardment forces."[178]

Oddly, at the end of his report, Lt Col Arnold appears to wish away the results, perhaps because pursuit were given the bombers' location, by concluding, "that Pursuit or fighter airplanes operating from front line airdromes will rarely intercept modern bombers except accidentally. Such being the case, they can normally operate solely against other Pursuits or Observation and it is doubtful whether such operations justify their existence."[179] On one hand Arnold stated pursuit (of the multi-seat type) are required to protect bombers, and that pursuit with bombers will force enemy pursuit to engage them first, yet ended with the strange statement that pursuit attacking pursuit and observation aircraft may not justify their existence.

Despite the contradiction, Arnold and many future leaders, including instructors at the ACTS, were aware of these results. Captain Claire Chennault, an instructor at the ACTS, responded to Lt Col Arnold's letter directly to the ACTS Commandant requesting his rebuttal entered into the official record. He countered not only Arnold's conclusions regarding a warning system and pursuit's efficacy under such a system, but also Arnold's conclusions regarding single versus multi-seat fighters.

Chennault's response provided a very in-depth analysis of Lt Col Arnold's letter, finding fault with many of the procedures and conclusions. He discussed current British interception capability including the use of observation listening posts (and how US antiaircraft

[178] Letter "Employment of Tactical Units Equipped with Modern Pursuit and Bombardment Airplanes," November 26, 1934, by Lt Col HH Arnold to the Chief of the Air Corps, Call # 248.282-15, in the USAF Collection, AFHREA, Maxwell AFB AL.
[179] Ibid, 18.

artillery units were similarly equipped) manned by a trained Observer Corps using devices for "determining altitude and course." He highlighted how the British demonstrated frequency and accuracy of position updates, discussing the 1933 RAF exercise whereby their interception system allowed the pursuit zone of action to be larger due to the Observer Corps' accuracy. Defensive pursuit no longer needed to know the enemy's objective--only current location. Chennault snidely remarked, "One might be excused for doubting that, in a situation where there are many possible objectives for hostile bombardment the pursuit commander will know the objective of each raid."[180]

He addressed the need for a national defensive system to be developed, concluding "that an effective aircraft reporting service must be organized and employed as the basis for interception missions by pursuit" with pursuit and AWS training occurring annually to test their ability to successfully intercept enemy aircraft. It also required more tests to determine organization, technique, and technical designs. Conversely, he attacked the non-standard tactics used during the exercise, stating the need for field forces to adhere to the standards in "The Role of Defensive Pursuit" until the validation of new tactics.[181] Results from a single exercise not following established doctrinal practices is not the basis for making decisions regarding an aircraft warning service and single or two-seat pursuit acquisition.

Regardless of the argument over single versus multi-seat fighters, the Air Corps at the highest levels and the ACTS as early as 1935 were aware of the efficacy of pursuit armed with information from a warning system versus the bomber. The March Field exercise highlighted the need for bomber escort, more so if the enemy had forewarning of an attack. Despite the lack of sophistication with something as consistent as radar

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[180] Letter from Captain Claire Chennault to The Commandant, ACTS, March 7, 1935, Call # 248.282-27, in USAF Collection, AFHRA, Maxwell AFB AL.
[181] Ibid.

for aircraft detection, the aircraft warning nets consisting of ground observers and listening devices had already proven to be effective enough to show the devastation defending pursuit could inflict on unescorted bombers. Airmen were sufficiently aware to recommend improving the warning net to increase detection rates. If the Air Corps was working on a means to improve detection, surely other nations were as well.

The Ft Knox Maneuvers, a combined AAA and Air Corps exercise, also held in May 1933, tested the intelligence network. The intelligence network consisted of an outer net with three rings around Ft Knox. The second inner intelligence net within 25 miles of Ft Knox had three radio fitted control cars and a fourth at the pursuit aerodrome, Bowman Field. The inner ring and the three cars flashed the latest information to the fourth control car for the pursuit operations officer to pass the latest updated bombardment information to pursuit aircraft after takeoff. Updated information ensured the success of many intercepts.[182]

The net headquarters consisted of an operations and intelligence section. The intelligence section received and filtered the data coming from the network and the operations section analyzed it and directed operations of both the network and pursuit aircraft. A comprehensive communications network tied the system together. As in other exercises, they compared red air flight data to reported data to verify the network's accuracy.[183]

Pursuit successfully intercepted bombardment, although bombardment had one target known to the pursuit. Regardless, the functional aspects of the intelligence net were considered good and efficient. The purpose was to detect and report hostile planes for

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[182] Joseph A. Green, Lieutenant Colonel, "The Fort Knox Distant Intelligence Net," *Coast Artillery Journal* (July-August 1933): 247-249.; "Summary of Reports of Ft Knox Exercise, Joint Antiaircraft-Air corps Exercise, May 15-27 1933," Call # 248.2124-13, in the USAF Collection, AFHRA, Maxwell AFB AL.

[183] Joseph A. Green, Lieutenant Colonel, "The Fort Knox Distant Intelligence Net," *Coast Artillery Journal* (July-August 1933): 247-249.

command to make timely decisions, launch pursuit, and intercept bombers. This occurred. Conceptually the system worked.[184]

Accuracy was critically important. Accuracy gave pursuit aircraft the enemy route, numbers, altitude, and formation in order to have the time needed to make an intercept.[185] Without accurate and timely information, pursuit could not be successful. This required the intelligence network to be as far out as possible, the same lesson Lt Col Reardon highlighted from the March Field Exercises. More time equaled greater opportunity for success.

As with the 1930 Aberdeen maneuvers, pursuit still did not attempt night intercepts. Airmen thought it difficult if not impossible to find an attacking aircraft at night unless searchlights had already located the bombers.[186] Observers helped and listening devices increased the probability of tracking, but this did not guarantee success.[187]

Oddly, despite all the arguing between Chennault and Walker, the latter in a preliminary Ft Knox report discussed the need for a single commander for pursuit, AAA, and the intelligence net, recommending an airman for the position. Since the intelligence net was essential to defending pursuit, and the entire early warning process too critical, the Air Corps needed to take the early warning/intelligence net concept seriously before another branch took control of it.[188]

The Joint AAA-AC exercise at Ft Bragg in October 1938 was a very large exercise designed to test an early warning command and control

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[184] "Summary of Reports of Ft Knox Exercise, Joint Antiaircraft-Air corps Exercise, May 15-27 1933," Call # 248.2124-13, in the USAF Collection, AFHRA, Maxwell AFB AL.

[185] Joseph A. Green, Lieutenant Colonel, "The Fort Knox Distant Intelligence Net," *Coast Artillery Journal* (July-August 1933): 251-252.

[186] K. N. Walker, 1st Lieutenant, "Driving Home the Bombardment Attack," *Coast Artillery Journal* (October, 1930): 339.; "Summary of Reports of Ft Knox Exercise, Joint Antiaircraft-Air corps Exercise, May 15-27 1933," Call # 248.2124-13, in the USAF Collection, AFHRA, Maxwell AFB AL.

[187] "The Solo Role of Antiaircraft Artillery in Air Defense," *Coast Artillery Journal* (June, 1930): 499.; Joseph A. Green, Lieutenant Colonel, "The Fort Knox Distant Intelligence Net," *Coast Artillery Journal* (July-August 1933): 247-249.

[188] "Discussion and Recommendation Pertaining to Air Corps--Antiaircraft Exercises Fort Knox--1933," Call # 248.2124-13, in the USAF Collection, AFHRA, Maxwell AFB AL.

network. Despite years of discussion, practice, and watching the British develop a system, the Army hoped "To devise methods for coordinating the action between Air Corps, antiaircraft artillery and the aircraft warning service 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 with the defended area." It also tested the AAA Intelligence network, and researched and tested using civilians as observers.[189]

The concluding report reiterated the results of other AAA-AC exercises since the 1920s: the need for an efficient AWS, the lack of effective detection devices, the need for faster fighters, and the absolute need of an air-warning network to conduct intercepts.[190] At the same time, it touted the ability of bombers to overcome defenses, stating, "Modern bombardment planes of the B-17 type, under favorable weather conditions can make attacks at such altitude and such speeds as to largely minimize effectiveness of the present AA guns, and Pursuit aviation."[191]

In Hawaii, November 1939, the Air Corps conducted searchlight, sound locator, and radio effectiveness tests. Despite bombers running with lights on, the conclusions were congruent with information derived since 1914 and well known to American Airmen. It is very difficult to intercept bombers without prior knowledge of location and at night it was near impossible—if it happened at all it was by accident. The exercise team knew of US radio detector research, knew of the British ability to track hostile aircraft by interception using radio detectors, and thus

[189] Letter from Adjutant General regarding Joint Antiaircraft – Air Corps Exercise, Fiscal Year 1939, February 23, 1938, AG 353 (1-31-38), Call # 248.2124-19, in the USAF Collection, AFHRA, Maxwell AFB AL.

[190] Report of Joint Anti-aircraft Corps Exercise, Fort Bragg, FY 1939, April 21, 1939, p. 2, 11, Call # 248-2124-18, in the USAF Collection, AFHRA, Maxwell AFB AL.

[191] Report of Joint Anti-aircraft Corps Exercise, Fort Bragg, FY 1939, April 21, 1939, p11, Call # 248-2124-18, in the USAF Collection AFHRA, Maxwell AFB AL.

recommended the Air Corps test the current radio detectors under development against existing sound locators.[192]

Events Around the World

Airmen were not oblivious to events around the world. Articles, manuscripts, attaché reports, and intelligence information made its way back to the US, including the ACTS. As a result, instructors and students were well aware of airpower's employment across a wide range of situations across the world.

The Sino-Japanese War demonstrated that an aircraft warning service unable to transmit information is worthless. The Chinese had an aircraft warning service, but no radios in their aircraft to receive information once airborne. Their ability to intercept and find aircraft was poor as a result. Once the system improved, it detected Japanese aircraft after they crossed the Chinese border and information flowed out across the country. The Japanese found once they began using pursuit escort with their bombers, bombing success rates and enemy kills increased while losses on their side dropped dramatically, becoming nonexistent on many raids. An unknown American observer in China summed up the role and influence of pursuit stating, "You can assure the boys and others who might be interested that pursuit still dominates the situation here in spite of bombardment's great speed." An Italian observer noted, "pursuit retains in full the value attributed to it in the past," while the Russian Air Attaché, Col Jigareff noted, "bombing planes ought to be required to have accompanying pursuit." Cooperation between pursuit and AAA confirmed the results of US exercises. Finally, the Air Corps

[192] (248.282-17A 7 Feb 29, 1940, Letter dated April 17, 1940 to the Chief of the air Corps regarding Pursuit-Searchlights tests conducted in Hawaii in Nov 1939 & ACTS April 9, 1940, An Evaluation of Questions Answered in Proceedings by a Board of Officers in the Hawaiian Department on Subject: "Cooperation of Pursuit Aircraft and Antiaircraft Artillery.")

officer writing the report recommended fitting pursuit aircraft with droppable fuel tanks to extend its range for bomber escort duties.[193]

Experience in the West suggested similar conclusions. The United Kingdom, Germany, France, Spain, and Italy recognized the need for a permanent air-warning network to provide enemy location and a communications network to regulate the action of aircraft in a "logical manner."[194] With a network, a trained controller could provide intercept control from the ground or air.[195] Major Carmagnat viewed the problem as an information management issue requiring the correct organization of command and communications systems to employ quickly and concentrate forces.[196] As with many Americans, he thought the use of ground observers as slow and inefficient.[197]

The Spanish Civil War highlighted the effects of a poorly established or executed intelligence-warning network. Gagarin, a Russian observer, noted that pursuit had to stay airborne in order to attack bombardment aircraft before bombardment released their weapons if given no early warning. He also noted the tactic of first having AAA then pursuit aircraft engage, but in all circumstances working together. Based on his observations, he recommended a senior air officer making decisions on launching pursuit or diverting airborne aircraft from other missions as necessary using radio communications.[198] A second Russian observer noted the success of the early warning system around

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[193] "Pursuit Aviation in the Sino-Japanese War," 1938-1939, by Captain A. J. Kerwin Malone, ACTS, Maxwell Field, AL, Call # 248.282-28, in USAF Collection, AFHRA, Maxwell AFB AL.
[194] "Light Fighter Aviation, 1935, by Major Carmagnat, French Army, Call # 248.282-10, p. 15, in the USAF Collection, AFHRA, Maxwell AFB AL.; Robert N. Mackin, Major, "Airplanes Can be Stopped," *Coast Artillery Journal* (September-October, 1937): 400.
[195] "Pursuit Light Fighter Aviation," 1935, by Major Carmagnat French Army, Call # 248.282-10, p. 29, in the USAF Collection, AFHRA, Maxwell AFB AL.
[196] Ibid, 39.
[197] Ibid, 30-32.
[198] "Aviation in Defensive Action-Spanish Civil War," 16 May 1938, by G. Gagarin, Call # 248.282-23, in the USAF Collection, AFHRA, Maxwell AFB AL.

Madrid in facilitating intercepts and the need for a "smoothly functioning aircraft warning service."[199]

The Spanish Civil War also demonstrated the effectiveness of a modern antiaircraft defense. The same Russian observer noted,

> Modern antiaircraft defense weapons, judging from the experience of the war in Spain, will also constitute a powerful means of antiaircraft defense. And yet the effectiveness of these weapons is far below that of the pursuit craft. Pursuit craft employed in cooperation with antiaircraft defense weapons may completely prevent any hostile bombers from reaching defended areas. Where an efficient aircraft warning service is in existence, this will usually be the case. The best method of cooperation between the pursuit craft and antiaircraft weapons is that in which the antiaircraft fire splits up the bombardment formation into separate groups or individual planes, with the pursuit craft entering the action after this has been accomplished. In this event the pursuit craft will have a better opportunity for the utilization of the advantages already referred to above.[200]

He noted the growing speed advantage of pursuit over bombardment and the advantage of defensive pursuit operating over home territory with an aircraft warning net. "In view of the experience of the Spanish conflict the modern pursuit aircraft may be considered a most formidable weapon, both as a means of antiaircraft defense and for general combat for control of the air."[201]

In 1936-1937, the side with better pursuit technology in the Spanish Civil War won air superiority.[202] Pursuit aircraft easily

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[199] "Tactical Employment of Pursuit Aviation-Spanish Civil War," 8 February 1938, by Mikhailow, Call # 248.282-23, in the USAF Collection, AFHRA, Maxwell AFB AL.
[200] "Aviation in Modern Combat," by G. Gagarin, *Ivanow, Krasnaya Zwesda*, Moscow, August 26, 1938, Call # 248.282, in the USAF Collection, AFHRA, Maxwell AFB AL.
[201] Ibid.
[202] Robert N. Mackin, Major, "Airplanes Can be Stopped," *Coast Artillery Journal* (September-October, 1937): 397, 399.

dominated engagements with bombardment, thus forcing bomber escort.[203] A French observer noted air superiority as the most important objective and the absolute need to have an early warning system. The Republican system included a ground observation network, listening devices to provide enemy track data, data plotting, and radio to control aircraft once launched from alert. Government forces also divided air into sector commands, under a single air force commander, and used telephone communications to ensure economy of force.[204]

The Air Corps, aware of events in Spain, agreed with several European commentators on the ability of pursuit aircraft to defeat older bombers, but not newer bombers. US observers noted that "piratical" bombing of cities, interpreted to mean raids of small numbers, possibly at low level—brought some success.[205] Pursuit had the advantage against bombardment aircraft employed in direct support of ground combat. Modern Republican bombardment aircraft attempted to avoid German and Italian pursuit, but required friendly pursuit to ensure success.[206] Conversely, the Air Corps thought even though the balance of evidence favored the fighters, bombers still had a "fair chance" of reaching the target by exploiting the initiative. US analysis did acknowledge the effectiveness of German AAA, credited with downing 80% of all aircraft, as well as the potency of pursuit and AAA working together.[207] Russian observers also confirmed AAA and pursuit effectiveness as a unit,[208] and

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203 "Aerial Warfare in Spain," Translated from *Revue de l'Armee de l'Air*, February 1937, Call # 248.282-23, pp. 185-198, in the USAF Collection, AFHRA, Maxwell AFB AL.

204 "The War in Spain, Tactics and Technique of the Air Forces," *Revue Militaire Generale*, by General Armengaud, French Army, April 1938, Call # 248.282, in the USAF Collection, AFHRA, Maxwell AFB AL.

205 Air Corps Newsletter, V-7676, A.C., April 1, 1938.

206 "The War in Spain, Tactics and Technique of the Air Forces," *Revue Militaire Generale*, by General Armengaud, French Army, April 1938, Call # 248.282, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report No. 6530-Spain, "Organizational Training. Tactics Employed," April 25, 1937, Call # 248.282-23, in the USAF Collection, AFHRA, Maxwell AFB AL.

207 *Air Corps Newsletter*, V-7676, A.C., April 1, 1938.; Robert N. Mackin, Major, "Airplanes Can be Stopped," *Coast Artillery Journal* (September-October, 1937): 399.

208 "Tactical Employment of Pursuit Aviation-Spanish Civil War" by Mikhailow, 8 February 1938, Call # 248.282-23, in the USAF Collection, AFHRA, Maxwell AFB AL.

how a large number of light bombers did not provide adequate protection against pursuit, thus requiring them to have pursuit protection.[209] Nonetheless, the Air Corps' confidence in the effectiveness of bombers remained unshaken.

As late as 1940, evidence regarding an early warning system requirement continued to reach the Air Corps. An uncannily prescient report from the Air Attaché's office in Finland reported Russian bombers turned back or released bombs early if attacked by Finnish pursuit. Conversely, Finnish pursuit avoided attacking Russian bombers or pursuit aircraft until they thought the enemy pursuit low on gas and turning back, due to the danger of attacking bombers accompanied by pursuit escort.[210] The British and Germans later used this tactic against pursuit aircraft. Captain Robert M. Losey, the American observer with the Finish Air Force, observed:

> 1. An adequate warning net manned by competent observers who can communicate directly with the proper pursuit commander is absolutely essential.
>
> 2. To be effective radio facilities for advising the pursuit in the air of the progress of the bombing raid must be available.
>
> 3. If unprotected bombardment are intercepted be even small numbers of pursuit, heavy losses of the former may be expected.
>
> 4. Until effective direct rear fire is possible from bombardment aircraft the direct rear attack by pursuit appears to be the best method.
>
> 5. Pursuit protected bombardment is very difficult to effectively attack.

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[209] "The Role of Light-Bombing Aviation in Modern Combat as Judged from Experience of the War in Spain," by K. Sinysokov. *Voyennaya Mysel*, Moscow, 1938, Call # 248.282, in the USAF Collection, AFHRA, Maxwell AFB AL.

[210] "Report No. 0051-Tactical Employment-Fighters," by Captain Losey, Finland, 20 Mar 1940, Call # 248.282-7, p. 2-3, in the USAF Collection, AFHRA, Maxwell AFB AL.

> 6. The two plane element is believed to be the most suitable basic pursuit unit.
>
> 7. It is quite desirable to have a very simple code system which will cover all normal communications between ground and air and between aircraft.[211]

Even before the Battle of Britain, the US knew the British used detection stations to identify aircraft at least out to 70 miles with altitude and flight path data. Britain's Fighter Command identified friend or foe and moved aircraft around to where needed.[212]

For night operations, the practice in Europe by 1936 included an aircraft reporting net with numerous searchlights.[213] The Russians observed, "In reporting night engagements between pursuit and bombardment aircraft, the great difficulty of finding a bomber without the help of searchlights is highlighted as a random event. With searchlights, close cooperation is required."[214] The British did not consider it sound tactics to use massed bombardment formations in daylight, especially with excellent visibility.[215] As such they relied on night bombardment during World War II, understanding the difficultly of night intercepts and the ease with which day pursuit with a warning net could intercept aircraft. The Air Corps may have sincerely believed this somehow did not apply to them and their heavy bomber, the B-17 Flying Fortress.

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211 "Report No. 0051-Tactical Employment-Fighters,"by Captain Losey, Finland, 20 Mar 1940, Call # 248.282-7, p. 4, in the USAF Collection, AFHRA, Maxwell AFB AL.

212 Report "Passive Defense, M.A. No. 40983," 19 March 1940, Call # 248.282, in the USAF Collection, AFHRA, Maxwell AFB AL.

213 Individual Research, "Pursuit Aviation," 1936-1937, by Captain Y. H. Taylor, ACTS, Maxwell Field, AL, Call # 248.282-11, in the USAF Collection, AFHRA, Maxwell AFB AL.

214 "Tactical Employment of Aviation at Night, Experience of the Spanish Civil War," by G. Ivanow, *Krasnaya Zwesda*, Moscow, August 17, 1938, Call # 248.282, in the USAF Collection, AFHRA, Maxwell AFB AL.

215 Report "Passive Defense, M.A. No. 40998, Eng," 31 January 1940, Call # 248.282, in the USAF Collection, AFHRA, Maxwell AFB AL.

Air Defense Command

In 1932, the United States established "four armies without fixed territorial bounds though located within the limits of specified Corps areas."[216] Air forces came under the General Headquarters Air Force (GHQ AF) upon its creation in 1935. Centralizing control over all tactical air units in the United States under a single commander gave the Commanding General, GHQ AF, "full control and responsibility for the peacetime development and training of aviation and means and methods of air defense."[217]

The coastal defense mission required extensive planning and coordination. By summer 1939, the Army was still determining where to locate detector sites, information centers, and aircraft warning units.[218] To make matters worse, coastal defense required close cooperation between aircraft, guns, and warning systems, and the fact most aircraft belonged to GHQ and most anti-aircraft guns belonged to coastal artillery commanders made this difficult.[219] Some people recommended the Air Corps solve this coordination problem, leading Arnold to propose formally to the Chief of Staff a new Air Defense Command, located in the northeastern United States under First Army, to study air defense doctrine and equipment.[220] Specifically, the proposal highlighted critical aspects for improving not only air defense but also command and control; the need for pursuit aircraft, the need to coordinate training of pursuit aircraft, AAA, and AWS, and the need for mobile air defense

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216 Stetson Conn, *Guarding the United States and Its Outposts* (Washington,: Office of the Chief of Military History Dept. of the Army; for sale by the Superintendent of Documents U. S. Govt. Print. Off., 1964), 17-19.
217 Conn and Fairchild, *The Framework of Hemisphere Defense*, 14.; Conn, *Guarding the United States and Its Outposts*, 29.
218 Dulany Terrett et al., *The Signal Corps: The Emergency (to December 1941)* (Washington,: Office of the Chief of Military History Dept of the Army, 1956), 136.
219 Conn, *Guarding the United States and Its Outposts*, 19-20.
220 Dr. C. L. Grant, "USAF Historical Studies: No. 126 the Development of Continental Air Defense to 1 September 1954," ed. USAF Historical Division Research Studies Institute (Air University, Maxwell AFB, Alabama), ix.; Conn and Fairchild, *The Framework of Hemisphere Defense*, 19-20.

operations. Arnold deplored the lack of joint training between AAA and pursuit aircraft, the lack of defensive tactics between aircraft, AAA, and the AWS, the inadequate and disorganized air defense, and stressed the need for a single commander. He described the coordination required of pursuit, AAA, and AWS to be more complicated than the coordination between pursuit and bombardment. In proposing to fix the situation, he recommended an Air Defense Command charged with joint training, developing tactics, techniques and procedures, reviewing all school texts for the three parts (pursuit, AAA, and AWS), and recommending the equipment requirements. Specific tactics, techniques and procedures addressed included splitting airborne pursuit to conduct multiple new intercepts, changing pursuit objectives mid-air, creating a communications net to meet new circumstances, controlling aircraft through an AWS covered area, avoiding communication congestion, avoiding fratricide, and ensuring complete tactical control of AAA and pursuit.[221] Arnold's plan was well received by the Chief of Staff and War Department, gaining immediate approval in principle for an Air Defense Command to coordinate and control AAA, aircraft, and AWS,[222] with questions regarding the organization of pursuit wings, manning, and a timeline for operational readiness to be addressed later.[223] Colonel (Brigadier General select) James E. Chaney was chosen to command the new organization.[224]

On 26 February 1940, Air Defense Command, similar in concept to unified commands defending London, Paris, and Berlin, stood up in the northeastern United States (Boston-New York-Detroit Industrial Triangle)

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[221] Memorandum for The Chief of Staff, "Air Defense," by Maj Gen HH Arnold, 24 November 1939, Call # 145.91-563, in the USAF Collection, AFHRA, Maxwell AFB AL.
[222] War Department Press Release, "Creation of an Air Defense Command," December 20, 1939, Call # 145.91-563, in the USAF Collection, AFHRA, Maxwell AFB AL.
[223] Memorandum for the Chief of the Air Corps, "Creation of an Air Defense Force," by Brig Gen F . M. Andrews, December 7, 1939, Call # 145.91-563, in the USAF Collection, AFHRA, Maxwell AFB AL.; *Air Corps Newsletter,* V-8323, A.C., 1 Jan 1940.
[224] War Department Press Release, "Creation of an Air Defense Command," December 20, 1939, Call # 145.91-563, in the USAF Collection, AFHRA, Maxwell AFB AL.

at Mitchel Field on Long Island under Chaney.[225] This area contained 80% of US war production capability.[226] Soon thereafter, on 1 March 1940, the 1st Aircraft Warning Company, Signal Corps and the 1st Operation Company, Signal Corps were activated "to coordinate Air Corps pursuit planes, Coastal Artillery anti-aircraft guns and searchlights, and Signal Corps detection and communications equipment."[227] To support this effort, the goal was to have a chain of radar sites 70 miles apart along both coasts.[228]

Only two months later, in May 1940, the Armies received responsibility for planning, sighting, and integrating warning devices. This continued to create confusion. The Chief of Air Corps lost control of GHQ AF when another reorganization on 19 November 1940 placed GHQ AF under GHQ. Despite this change, General Arnold's role as Deputy Chief of Staff still gave him influence over GHQ AF operations. Defense commands under GHQ continued to be in charge of air and ground defense, led by Army Commanders.[229] The organizational structure continued to evolve as the Army expanded.

In early 1941, General Arnold advocated to General Marshall in two letters that Air Defense was an Air Corps responsibility. This required more Air Defense Commands to train pursuit forces and that the Signal Corps AWS should be included in the organization as originally requested in 1939. The pursuit-aircraft warning team required a common command agency and habitual training to include AAA. He recommended one Air Defense Command per theater with the

[225] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 149-50.; "Our New Air Defense Forces," *U.S. Air Services* XXVI, no. 5 (May, 1941): 12.; Memorandum for The Chief of Staff, "Air Defense," by Maj Gen HH Arnold, 24 November 1939, Call # 145.91-563, in the USAF Collection, AFHRA, Maxwell AFB AL.
[226] Air Corps Newsletter, V-8335 A.C., 15 January 1940.
[227] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 149-50.; "Our New Air Defense Forces," *U.S. Air Services* XXVI, no. 5 (May, 1941): 12.
[228] Grant, "USAF Historical Studies: No. 126 the Development of Continental Air Defense to 1 September 1954," ix.
[229] Conn, *Guarding the United States and Its Outposts*, 24, 28.

requirement all parts be interchangeable and mobile. General Arnold indirectly advocated creating standards, allowing rapid deployment, integration into existing operations, and improving efficiency for a nascent command and control capability.[230] The proposal also included a recommendation for four ADCs in the U.S., one in the Caribbean and one in Hawaii, with the GHQ AF in charge of training, defense studies, plans, and integrating with the Army and Navy.[231]

The success of Air Defense Command in the Northeast, coupled with Arnold's recommendation, led to an expansion of Air Defense Command throughout the United States in March 1941 and the creation of four air districts (numbered) and defense commands (geographically titled), falling under the four continental armies. These were the Northeastern, Central, South and Western commands.[232] For Air Defense, the United States was broken down into sectors, each having an Aircraft Warning Service (AWS) with up to 20 observation posts connected via local telephone service and broadcast radio AAA and fighter aircraft.[233]

Air Defense Command provided the model for the four continental interceptor commands created under Air Force Combat Command in June 1941. Under the continental interceptor commands were 19 air defense regions, each with a pursuit group and aircraft warning

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[230] Memorandum for The Chief of Staff, "Organization of Air Defense Commands," by Maj Gen HH Arnold, February 3, 1941, Call # 145.91-563, in the USAF Collection, AFHRA, Maxwell AFB AL.; Memorandum for General Marshall, "Hemisphere Defense," by Maj Gen HH Arnold, February 20, 1941, Call # 145.93-143, in the USAF Collection, AFHRA, Maxwell AFB AL.

[231] Memorandum for The Chief of Staff, "Organization of Air Defense Commands," by Maj Gen HH Arnold, February 3, 1941, Call # 145.91-563, in the USAF Collection, AFHRA, Maxwell AFB AL.; Memorandum for General Marshall, "Hemisphere Defense," by Maj Gen HH Arnold, February 20, 1941, Call # 145.93-143, in the USAF Collection, AFHRA, Maxwell AFB AL.

[232] Conn, *Guarding the United States and Its Outposts*, 24, 28,135.; "Army Air Corps Reorganization Announced," *U.S. Air Services* XXV, no. 11 (November, 1940): 12.; AAFSAT Course Lecture, "Orientation-The Air Defense," May 1944, Call# 248.25-25, in the USAF Collection, AFHRA, Maxwell AFB AL.

[233] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 41, 86.; AAFSAT Course Lecture, "Orientation-The Air Defense," May 1944, Call# 248.25-25, in the USAF Collection, AFHRA, Maxwell AFB AL.

organization. The aircraft warning organization received information into its central information center from the few available radars and civilian observers and then alerted various air defense elements including interceptors and civil defense.[234] Although Air Corps forces fell under the commanders of the armies in each area, the aircraft from Interceptor Command were separate special units dedicated to air defense under GHQ AF control.[235] In reality, Air Forces remained under east and west theater commanders.

Coupled with all the changes occurring with air defense, the Army Air Corps also underwent a major restructuring with the release of *Army Regulation 95-5* on 20 June 1941, creating "the Army Air Forces as a semi-autonomous body within the Army." GHQ AF became Air Force Combat Command and placed under the Chief of the Army Air Forces, Lieutenant General Arnold.[236] This reorganization gave the Army Air Forces more autonomy and centralized many of the planning and air defense functions providing for a more coherent long-term planning strategy.

After Major Chennault left the ACTS, Captain Gordon P. Saville took his place as the main advocate for pursuit aircraft. He became intimately involved in developing Air Corps command and control doctrine. Despite Air Defense Command's activation in February 1940, it took until October 27, 1941 for an official "Air Defense Doctrine," prepared by Major Saville, to appear. This document served as the foundation for the later, more official Air Warning Signal regulation to appear in 1942.

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[234] Grant, "USAF Historical Studies: No. 126 the Development of Continental Air Defense to 1 September 1954," ix.

[235] US Air Service, May 1941, p 12.; Grant, "USAF Historical Studies: No. 126 the Development of Continental Air Defense to 1 September 1954," ix.

[236] Colonel Byron E. Gates, "Organization of the Army Air Forces," *Air Force: Official Service Journal of the U.S. Army Air Forces* Vol 26, no. 2 (February, 1943): 13.

It defined the purpose of the aircraft warning service: to obtain early, accurate information, evaluate it, and display it for a decision maker. The aircraft warning service provided early warning and the intercepting function, distinguishing between fixed and mobile due to the size of the US and need to communicate with aircraft as they traversed long distances.[237] Many of the ideas and functions mirrored the British, which Major Saville had seen in action.[238]

The Air Defense structure and processes created in the US and used for training served as the early model for command and control processes, and eased the transition to the combat theaters. Air Defense Commands, sometimes called Fighter Commands, had regions controlled by wings comprised of an Aircraft Warning Service, AAA, fighter aircraft, and a centralized ground control system. All information flowed into the Region Operations Room for the Region Commander to make decisions regarding the defense of his area of responsibility. Centralized information such as weather data, aircraft status, radar status, and enemy positions were available for immediate decision-making by the commander. The regions, controlled by the wings, had sub areas called Fighter Control Areas with tactical Headquarters and Area Operations Rooms, which contained information on enemy location and friendly aircraft and where the actual control occurred.[239] The AAA room was collocated with the operations room.[240] The Area Controller, later called the Fighter Sector Controller located in the operations room, exercised

[237] "Air Defense Doctrine," prepared by Major Gordon P. Saville, October 27, 1941, Call # 145.96-120, in the USAF Collection, AFHRA, Maxwell AFB AL.
[238] Oral History Interview of Maj Gen Gordon P. Saville by Mr. Thomas A Sturm, 26-29 March 1973, typed transcript, Call # K239.0512-1322 C.1, in the USAF Collection, AFHRA, Maxwell AFB AL.
[239] AAFSAT Course Lecture, "Fighter Control in Air Defense," June 1944, Call # 248.25-2, in the USAF Collection AFHRA, Maxwell AFB AL.; AAFSAT Course Lecture, "Orientation Concerning Controlled Intercept," 1942, Call # 248.25-3, in the USAF Collection, AFHRA, Maxwell AFB AL.; AAFSAT Course Lecture, "Introduction to Course in Basic Control," February 1944 Call # 248.25-1, in the USAF Collection, AFHRA, Maxwell AFB AL.;
[240] *Signal Corps Field Manual, FM 11-25, Aircraft Warning Service, Change 1*, War Department, Washington, March 10, 1943.

operational control of all air defenses in his area and reported directly to the Fighter Commander.[241]

Planning for War

A series of air defense exercises occurred between 1937 and 1939. The results of the 1937 and 1938 exercises led to a plan to buy the mobile SCR-270 (Signal Corps Radio), an early warning radar set, by August 1940, with 31 mobile sets at eleven sites on the Northeast Atlantic and ten on the Pacific coast.[242] Thorough radar coverage of the US, extending to Mexico and Canada, was the goal. A proposal in early 1941 to cover Baja California with radars and ground observers led to agreements with Mexico for their installation and eventual staffing by not only American, but also Mexican military personnel.[243] Canada was a belligerent since September 1939, and American ties to Britain led to increased cooperation in 1940-41.[244] US defense plans, initially based on the threat of a Nazi attack into the Western Hemisphere, proved unnecessary. A postwar interview with Field Marshal Wilhelm Keitel, one of the senior Nazi planners, revealed the Germans had no plans to invade the Americas, stating, "Hitler expected to complete his European conquests before the United States could possibly intervene."[245]

Nonetheless, America's policy and defense plans hinged on keeping Germany and Japan out of the Western Hemisphere.[246] The United States did not anticipate a German invasion until the fall of 1940 at the earliest and by then expected to have 1.4 million men in the Army and a

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[241] AAFSAT Course Lecture, "Fighter Control in Air Defense," June 1944, Call # 248.25-2, in the USAF Collection AFHRA, Maxwell AFB AL.; AAFSAT Course Lecture, "Fighter Sector Controlling," February 1944, Call # 248.25-2, in the USAF Collection AFHRA, Maxwell AFB AL.; AAFSAT Course Lecture, "Introduction to Course in Basic Control," February 1944 Call # 248.25-1, in the USAF Collection, AFHRA, Maxwell AFB AL.; *Signal Corps Field Manual, FM 11-25, Aircraft Warning Service, Change 1*, War Department, Washington, March 10, 1943.
[242] Conn, *Guarding the United States and Its Outposts*, 61-62.
[243] Conn and Fairchild, *The Framework of Hemisphere Defense*, 356-63.
[244] Conn, *Guarding the United States and Its Outposts*, 7-8.
[245] Conn and Fairchild, *The Framework of Hemisphere Defense*, 68-69.
[246] Craven and Cate, *The Army Air Forces in World War II, V. 1,* 102.

stronger Navy to face the unlikely eventuality.[247] By December 1940 however, civilian and military leaders were convinced the US must eventually enter the war against Germany. Planning now began to assume an offensive as well as a defensive character. It would be December 1941 before enough Army forces became available to begin offensive operations overseas and alleviate the need for defensive planning.[248]

Military leaders began planning for the anticipated shift in US defense policy calling for projecting power outside the country. By June 1939, a report of the Army Air Board recommended 324 pursuit aircraft and a combination of light, medium, and heavy bomber aircraft totaling 330 to provide defense, reinforce overseas positions, and provide "expeditionary striking forces within Western Hemisphere."[249] The onset of war in September 1939 brought a reassessment to 68 bombers and 270 pursuit aircraft for defense. The United States believed it could defend against a two-carrier strike on either coast, reaffirming the numbers again in May 1940.[250]

War in Europe and America's initial non-involvement in it created a situation where Air Corps planners attempted to formulate response plans, because having no plan would lead to chaos. An Air Corps analysis in November 1940 delineated three possible courses of action: hemisphere defense, offensive action in the East, and offensive action in Europe. At the time, only hemisphere defense was a viable option given America's neutrality. On 29 November 1940, General Marshall approved the Air Corps recommendation to focus on hemisphere defense.[251] This was either good fortune or vision on the part of the Air Corps and General Marshall. It aligned with President Roosevelt's defense policy and

[247] Conn, *Guarding the United States and Its Outposts*, 10-11.
[248] Ibid, 11, 15.
[249] Ibid, 54-55.
[250] Ibid, 56.
[251] Conn and Fairchild, *The Framework of Hemisphere Defense*, 90.

provided the Army and the Air Corps a focused mission to support not only defense, but also training and the acquisition of equipment to conduct offensive operations when the time arrived.

Not all necessary planning and preparation occurred, even as it became clear the US would probably enter the war soon. Despite the Air Defense Board's September 1941 recommendation to expand the AWS by 2,200 officers and 40,200 men, the AWS requested only 900 officers and 17,000 men in November. Sending the cadre of trained men around the world and into new and expanding units to form the core of expertise exacerbated the situation.[252] Keeping in line with the official American defensive position, the first set of trained men and equipment went to Panama with plans to send more to Alaska and Hawaii.[253] The Army planned to use the National Guard for AWS and home defense, and the regular Army overseas.[254]

Ambitious expansion plans failed not only to account for manning problems, but also for organizational and equipment problems. The planned 31 mobile sets for both coasts failed to materialize. Only two on the east coast and six on the west coast were operational by 7 December 1941.[255] Hawaii had several SCR-270s, one operating and tracking the incoming Japanese air fleet, but the organizational structure failed to respond to the data.[256]

World events motivated changes and drove preparations for war. The changes occurred in the context of American neutrality, geographic isolation, and the feeling war was still some time away, but required

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[252] George Raynor Thompson, *The Signal Corps: The Test (December 1941 to July 1943)* (Washington,: Office of the Chief of Military History Dept. of the Army, 1957), 4, 24.
[253] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 151.
[254] Louis Brown, *A Radar History of World War II: Technical and Military Imperatives* (Bristol, UK ; Philadelphia: Institute of Physics Publishing, 1999), 39.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 161.
[255] Grant, "USAF Historical Studies: No. 126 the Development of Continental Air Defense to 1 September 1954," ix.
[256] Brown, *A Radar History of World War II*, 72-73.

preparation. Preparation progressed moderately, but was not complete by December 1941.

Processes

Fighter Control Procedures

Fighter control presented a problem of recognition and identification. A system was necessary to control, correlate, and act on the information gathered during recognition and identification. The main components of this system included the early warning radar, the filter room, the Fighter Command organization, and the control system. Radar detected enemy aircraft while VHF located, communicated with, and controlled friendly aircraft.[257] VHF used D/F stations, situated in an area where friendly fighters operated. These stations located fighters by picking up a transmitted signal from friendly aircraft. Equipment on an aircraft transmitted a signal for fifteen seconds and a D/F clock in the Fighter Control Area Operations D/F Room picked up the signal. The controller used this signal to track up to four flights, giving each flight a fifteen second transmit time slot and synchronizing this to the D/F clock. The aircraft VHF radio set had four channels dedicated to sending out this signal.[258] The British called this "pip-squeak;" the American term was "contactor."[259] D/F stations could be either fixed or mobile, placed approximately 40 miles apart, and provided a range of 100 miles. At least two stations were required to obtain a bearing on the aircraft. Friendly fighter location could be 20 seconds old due to transmission and processing speeds, but it did provide the fighter controller with constant friendly fighter information.[260]

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[257] AAFSAT Course Lecture, "Orientation Concerning Controlled Intercept," 1942, Call # 248.25-3, in the USAF Collection, AFHRA, Maxwell AFB AL.
[258] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 79.; AAFSAT Course Lecture, "Orientation Concerning Controlled Intercept," 1942, Call # 248.25-3, in the USAF Collection, AFHRA, Maxwell AFB AL.
[259] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 79-80.
[260] AAFSAT Course Lecture, "Orientation Concerning Controlled Intercept," 1942, Call # 248.25-3, in the USAF Collection, AFHRA, Maxwell AFB AL.

The fighter control process before GCI and the PPI was extremely tedious, manual, and labor intensive. The Area or Fighter Sector Controller was assisted by a large team to include, the intercept officers that talked to fighters, a Ground Control Intercept (GCI) Controller when done with a radar station, a Filter and Identification officer, plotters, AAA operations officer or liaison, communication specialist and myriad of other people to manage the flow and recording of information.[261]

First, information from several radars flowed into the radar filter room where Plotters, in constant telephone contact with the radar stations (usually SCR-270s), plotted the information on a map before sending it to the Wing and Area Operations Room for display and use by the Wing and Area Controllers to launch pursuit aircraft as necessary. The Filter Officer averaged radar information, including location, numbers, and height, from all the radar stations. Finally, if available, each radar station passed IFF information to the filter room. Personnel crosschecked this information to ensure no friendly aircraft without an IFF system was in the area. A Speed Orderly calculated track speeds after several iterations between the radar stations and the Filter Officer. Intelligence data, provided by radio intelligence or "Y" service operators, added additional data passed directly to the Area Operations Room.[262]

At first, intercepts were not conducted directly from radar scopes, but manually from charts. To handle this difficult task, the controller had two assistants. One received the D/F information on friendly aircraft and the second received enemy radar information and plotted this information on a chart allowing the controller to control four intercepts

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[261] AAFSAT Course Lecture, "Introduction to Course in Basic Control," February 1944 Call # 248.25-1, in the USAF Collection, AFHRA, Maxwell AFB AL.; *Signal Corps Field Manual, FM 11-25, Aircraft Warning Service, Change 1*, War Department, Washington, March 10, 1943.

[262] AAFSAT Course Lecture, "Orientation Concerning Controlled Intercept," 1942, Call # 248.25-3, in the USAF Collection, AFHRA, Maxwell AFB AL.; AAFSAT Course Lecture, "Fighter Control in Air Defense," June 1944, p. 2, Call # 248.25-2, in the USAF Collection, AFHRA, Maxwell AFB AL.; *Signal Corps Field Manual FM 11-25, Aircraft Warning Service*, August 3, 1942.; & (CAJ Mar-April 1940, p. 157)

at once. Additionally, to prevent fratricide, the controller had to coordinate with anti-aircraft artillery.[263]

The final part of the air defense system was the Ground Observer. Observation posts usually placed six to eight miles apart and connected via telephone lines reported information back to the Filter Center.[264] Ground observer data arrived at the ground observers filter room and "told" to the Radar Filter Room. "Telling" was the term to describe the passing of data from one person or organization to another. Fusing ground and radar data with intelligence provided a more complete picture before going to the Operations Room.[265] Ground Observers were civilian volunteers, men, women, boys, and girls. The First Fighter Command in charge of East Coast defense had over 8,000 observation posts with almost 1 million volunteers.[266] By April 1943, over 1.5 million ground observers existed nationwide.[267]

Technology

The basic technological requirements for an air command and control system are a means to communicate, a means to detect and track the enemy, and a means to process the information. The Army wasted little time after World War I, despite massive budget cuts, to research, develop, and conduct field tests on aircraft, radios, and sound and visual devices.[268]

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263 AAFSAT Course Lecture, "Orientation Concerning Controlled Intercept," 1942, Call # 248.25-3, in the USAF Collection, AFHRA, Maxwell AFB AL.

264 AAFSAT Course Lecture, "Orientation Concerning Controlled Intercept," 1942, Call # 248.25-3, in the USAF Collection, AFHRA, Maxwell AFB AL.; Gordon P. Saville, Brigadier General, "Our Air Defense Network," *Air Force: Official Service Journal of the U.S. Army Air Forces* Vol 26, no. 4 (April, 1943): 15.

265 *Signal Corps Field Manual, FM 11-25, Aircraft Warning Service, Change 1*, War Department, Washington, March 10, 1943.; AAFSAT Course Lecture "Fighter Control in Air Defense," June 44, p. 2, Call # 248.25-2, in the USAF Collection, AFHRA, Maxwell AFB AL.

266 AAFSAT Course Lecture, "Orientation Concerning Controlled Intercept," 1942, Call # 248.25-3, in the USAF Collection, AFHRA, Maxwell AFB AL.

267 Grant, "USAF Historical Studies: No. 126 the Development of Continental Air Defense to 1 September 1954," ix.

268 Benjamin F. Harmon, Captain, "The Archies and the Antiaircraft Service," *Coast Artillery Journal* (June, 1922): 532.

Considering the limited resources available to the Army, the progress made developing and improving new technologies during the 1920s was remarkable. Indeed, the Air Service between 1919-1924, despite budget cuts and public indifference toward military preparedness experimented significantly.[269] Its limited research budgets focused mainly on aircraft and research in other areas such as detection devices and radios it left to other branches.

Listening Devices

Attempts to find ways to detect aircraft began immediately after WWI. In June 1919, the Signal Corps began experiments with thermal, sound, and other detection methods that continued until 1939. The CAC served as the primary organization pushing for improved and new technologies such as an acoustic apparatus to direct effective AAA fire.[270] They integrated sound devices and searchlights as a means of identification due to the very low probability of either device finding an aircraft on its own. At night, a searchlight flash system challenged aircraft for a response to aid in identification.[271] Exercises held at Fort Dix in 1925 confirmed the ability of searchlights and listening devices to work together providing accuracy to about 12,000 yards for listening devices and between 6000 and 15000 yards for searchlights.[272] The post exercise report recommended improving the range and accuracy of listening devices.[273]

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[269] *USAF Historical Study No, 20, Comparative History of Research and Development Policies Affecting Air Materiel 1915-1944* (Prepared by AAF Historical Office Headquarters, Army Air Forces, June 1945), 30.

[270] Thomas R. Phillips, Captain, "Some Phases of the Effect of Aircraft on the Future Mission, Organization, Equipment and Tactics of the Coast Artillery Corps," *Coast Artillery Journal* (March 1923): 211-212.; H. R. Oldfield, Major, "Organization of Ground Means of Antiaircraft Defense," *Coast Artillery Journal* (April 1925): 282.

[271] H. R. Oldfield, Major, "Organization of Ground Means of Antiaircraft Defense," *Coast Artillery Journal* (April, 1925): 285.; Benjamin F. Harmon, Captain, "The Archies and the Antiaircraft Service," *Coast Artillery Journal* (June, 1922): 548.

[272] C. L'H. Ruggles, Brigadier General, "Antiaircraft Defense," *Coast Artillery Journal* (March, 1926): 226.

[273] "Report of Antiaircraft Service and Air Service Exercises, Ft Tilden NY & Ft Dix, NJ," 1925, Call # 248.2124-5, p. 36, in the USAF Collection, AFHRA, Maxwell AFB AL.

The Army was well aware of the issues and limitations of sound listening devices, such as precision location mainly due to sound lag and wind,[274] the lack of well-trained listeners (trained to differentiate the sound on various aircraft) and no scientific method for testing the ears of listeners.[275] The Army acknowledged the need to either improve on those devices or look for other technologies or methods to track aircraft in flight to enable both early warning and fire control. Some advocated for abandoning sound and searching for new methods while others advocated improving sound listening technology.

The CAC, the primary driver of improving detection technology, addressed the limitations of the equipment by building better equipment and through better training. New devices more accurately indicated aircraft approach paths and altitude, visual techniques to measure height and velocity (using long range cameras & motion film) improved, and aircraft capabilities and possible enemy objectives were studied to accurately plot enemy aircraft and transmit the information to higher headquarters.[276] These efforts attempted to improve the overall system for not only day operations, but also at night and during bad weather.[277]

After the war, the army continued using existing sound technology before commencing tests of new devices in 1924. One of those devices was a two-horned device (single horned devices existed) that was superior to older methods. This device depended

> for operation upon the binaural principle or the binaural sense. The sound locator merely

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[274] H. B. Ely, Lieutenant, "Sound Locators: Their Functions and Limitations," *Coast Artillery Journal* (August 1926): 128.; J.C. Haw, Major, "Antiaircraft Defense," *Coast Artillery Journal* (October, 1925): 320-321.; H. M. Davis, First Lieutenant, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I: Early Research and Development – 1918-1937* (Historical Section Field Office, Office of the Signal Corps Officer, Army Service Forces, 27 March 1943), xiii, 5.

[275] H. B. Ely, Lieutenant, "Sound Locators: Their Functions and Limitations," *Coast Artillery Journal* (August 1926): 127.; Aaron Bradshaw, Jr., Captain, "Recent Developments in Antiaircraft Materiel," *Coast Artillery Journal* (May, 1923): 450.; Benjamin F. Harmon, Captain, "The Archies and the Antiaircraft Service," *Coast Artillery Journal* (June, 1922): 545.

[276] C. G. Mettler, Major, "Antiaircraft," *Coast Artillery Journal* (December 1925): 551.

[277] Benjamin F. Harmon, Captain, "The Past and Future of Defense Against Aircraft," *Coast Artillery Journal* (December 1925): 565.

> extends the ears through two large horns at the ends of a base line longer than that of the two ears so that the phase difference for a given angle will be greater, thus sharpening the binaural effect. In addition, an amplification is obtained by properly designed horns and the incoming sound wave can be heard several times louder than with the naked ear. Two horns are used for azimuth and two in the plane at right angles to that of the first two for elevation determination. The small ends of the horns extend through flexible tubes to earpieces contained in a leather helmet worn by the operator. The horns are mounted on a single pedestal and are manipulated in azimuth and elevation by hand wheels. They are capable of swinging through the full circle in azimuth and to minus ten degrees on both sides of the zenith.[278]

The dependence on the human ear drove new experiments using electrical detectors to increase accuracy and range. Other methods explored improving visual detection, measuring radio waves from aircraft engines, and sensing or shooting heat waves and looking for rebounded energy.[279] This led to the development of a device to measure heat against the sky from heat radiating from aircraft. Sound and heat appeared to be the preferred methods in the 1920s despite also exploring visual means and radio waves.[280]

The Air Service was well aware other nations had listening devices and would have to face them, as experience in WWI demonstrated.[281]

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[278] H. B. Ely, Lieutenant, "Sound Locators: Their Functions and Limitations," *Coast Artillery Journal* (August 1926): 126.

[279] *History of the Army Air Forces Proving Ground Command: Part XVI-Testing of Radio and Radar Equipment* (The Historical Branch, Army Air Forces Proving Ground Command, Eglin Field, Florida, 1945), Call # 240.04-10 V1, in the USAF Collection, AFHRA, Maxwell AFB AL.

[280] Aaron Bradshaw, Jr., Captain, "Recent Developments in Antiaircraft Materiel," *Coast Artillery Journal* (May, 1923): 455.; William Sackville, Captain and J. E. Olivares, Lieutenant, "A Suggestion for a New Method of Locating Aircraft at Night," *Coast Artillery Journal* (May, 1927): 411-414.; Radar, Part 1, p13

[281] H. B. Ely, Lieutenant, "Sound Locators: Their Functions and Limitations," *Coast Artillery Journal* (August 1926): 124.

European scientists were also working on such devices to improve their warning and fire control capabilities. Brigadier General C. L'H. Ruggles, Ordnance Department, in his statement to the President's Antiaircraft Board, commented on his trip to Europe to investigate "antiaircraft defense, that the leading European countries are convinced of the necessity for antiaircraft defense, and that the belief is general that the efficiency of this defense will rapidly increase due to improvement in training methods and in materiel."[282]

Despite the problems with sound locators, the Army continued using them throughout the 1930s receiving its last one in the later part of the decade. They were not alone, as Europeans continued to improve their devices, integrated them, searchlights and fire control systems into their growing intelligence networks.[283] The latest model was still used during the 3rd Army Maneuvers of 1940, but continued suffering from all the same issues.[284]

Radar

US defense policy and the sky's vastness made some aircraft defense system necessary. Therefore, this research area received funding even during lean budgetary years,[285] not from the Air Corps but rather the Signal Corps. Major William Blair, an engineer and Director of the Signal Corps Laboratories at Fort Monmouth, NJ, since his time as a student at the Army's Command and General Staff College in Fort Leavenworth in 1926, believed microwaves were the best choice for solving the radar problem.[286] In June 1926, as the Officer in Charge of the Research Engineering Division, Office of the Chief of Signal Officer,

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[282] C. L'H. Ruggles, Brigadier General, "Antiaircraft Defense," *Coast Artillery Journal* (March, 1926): 226, 235.

[283] Joseph A. Green, Lieutenant Colonel, "The Fort Knox Distant Intelligence Net," *Coast Artillery Journal* (July-August 1933): 251-252.; Professor Doctor Christian von Hofe and Doctor Hans Raaber, "Listening Devices and Additional Instruments," *Coast Artillery Journal* (September-October 1932): 332.

[284] Davis, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I:*, xiii.

[285] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 27, 35.

[286] Brown, *A Radar History of World War II*, 44, 69.

he testified to the technical committees of the Ordnance Department and Coast Artillery Corps of sound's inadequacy as a detection method. He thought heat or high frequency radio detection should receive more funding.[287] His prediction came true, although not without some intermediary steps.

As early as 1885, Hertz demonstrated radio wave reflection from objects. The wave interference method, first observed in the US in the 1920s, occurred when a radio wave reflected back on itself created a wave interference pattern. The Navy Aircraft Radio Laboratory had detected surface vessels with radio waves in 1922,[288] and by the late 1920s, pulse beams detected the ionosphere.[289] Research continued both in the military and in the industrial sector for a method to detect objects with radio waves.

On 10 December 1930, Dr. A. Hoyt Taylor of the Naval Research Laboratory demonstrated Doppler method radar equipment to the Signal Corps, Air Corps, and Coast Artillery. His machine used beat detection to determine aircraft position. Beat detection worked by observing signal changes in a receiver as an object transitioned through the radio propagation field.[290] This method sufficed for general aircraft location, but did not provide the target's exact coordinates. Taylor submitted his findings to the Chief of the Bureau of Engineering. The Secretary of Navy then sent it to the Secretary of War on 9 January 1932 saying, "Certain phases of the problem appear to be of more concern to the Army than to the Navy. For example, a system of transmitters and associated receivers

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[287] H. M. Davis, First Lieutenant, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I: Early Research and Development – 1918-1937* (Historical Section Field Office, Office of the Signal Corps Officer, Army Service Forces, 27 March 1943), 19.
[288] Davis, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I*, 21.
[289] Roger B. Colton, "Radar in the United States Army," *Proceedings of the Institute of Radio Engineers* (November, 1945): 741.
[290] Robert Morris Page, *The Origin of Radar*, 1st ed. (Garden City, N.Y.,: Anchor Books, 1962), 25.; H. M. Davis, First Lieutenant, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I: Early Research and Development – 1918-1937* (Historical Section Field Office, Office of the Signal Corps Officer, Army Service Forces, 27 March 1943), 21.; Bowen, *Radar Days*, 6.

might be set up about a defense area to test its effectiveness in detecting passage of hostile craft into the area. Such a development might be carried forward more appropriately by the Army than by the Navy." The Signal Corps already knew of the extent and type of work when it officially received a copy of the report.[291] The Air Corps and the Navy were aware of its potential use--early warning to provide the necessary time to alert, scramble, and intercept an enemy. The Signal Corps saw nothing of value in the demonstration. It was looking for radar to provide the exact firing data for its anti-aircraft artillery guns.[292] As a result, the Army continued to look into other means for aircraft detection.

In 1931, "Project 88" transferred from the Office of the Chief of Ordnance to the Signal Corps Laboratories at Fort Monmouth. This project initially examined infrared and heat rays, but later expanded to include radio waves in 1932 due to the deficiencies of heat detection. The exercises in 1933 at Fort Knox confirmed the deficiencies of thermal aircraft warning devices despite the massive effort given to infrared detection, opening the way for other methods of detection to be more readily accepted. In July 1934, a radar program using pulses began at Fort Monmouth.[293] This led to years of research and finally a Signal Corps test on 14 December 1936 of its first pulse machine, detecting an aircraft over Newark airport. It was a crude machine, tracked aircraft out to only seven miles, and required a one-mile separation between the transmitter and receiver. Nonetheless, it showed the concept worked.[294]

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[291] H. M. Davis, First Lieutenant, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I: Early Research and Development – 1918-1937* (Historical Section Field Office, Office of the Signal Corps Officer, Army Service Forces, 27 March 1943), 22.

[292] Brown, *A Radar History of World War II*, 43.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 40.

[293] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 39.; Brown, *A Radar History of World War II*, 39, 44.; Davis, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I,* 29.

[294] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 46.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 71.; Roger B. Colton, "Radar in the United States Army," *Proceedings of the Institute of Radio Engineers* (November, 1945): 743.; Davis, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I,* 44.

The Army could now see the exact location of an aircraft, rather than where it used to be.

In the winter of 1936-37, GHQ AF helped the Signal Corps with radar tests by providing aircraft.[295] By February 1937, detection range increased to ten miles and 23 miles in March when it successfully tracked a B-10B bomber, but still with an azimuth error of 7-8 degrees.[296] The large azimuth error was not good enough for detection and continuous tracking. Testing continued and by April, with reliable azimuth and height,[297] they were now ready to demonstrate the device.

The radar set tested at Fort Monmouth on 18-19 May 1937, with the Chief Signal Officer, Chief of Coast Artillery, Assistant Chief of the Air Corps, and representatives from the Ordnance Department and Corps of Engineers in attendance, became the SCR-268, a gun laying radar. Initially the radar had three separate antennas, one for transmitting, one for receiving, and one for determining target elevation. However, it could "locate airplanes at night, in range, elevation and azimuth," had an effective range of 30 miles, but could see aircraft to 60 miles. Moreover, its design as a fire control system for anti-aircraft artillery made it mobile and allowed it to locate targets and direct guns and searchlights. By the time deliveries began in February 1941, engineers combined the three antennas into a single antenna.[298]

A successful demonstration on 26 May 1937 for the Secretary of War, Chief of Staff, Chief of the Air Corps, and members of the Senate and House Military Affairs Committee demonstrated radar worked, was practical, and required more money and effort.[299] After the test, the

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[295] Davis, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I,* 46.
[296] Roger B. Colton, "Radar in the United States Army," *Proceedings of the Institute of Radio Engineers* (November, 1945): 743.
[297] Davis, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I*, 47.
[298] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 46-47, 127.; Brown, *A Radar History of World War II*, 71-72.
[299] Roger B. Colton, "Radar in the United States Army," *Proceedings of the Institute of Radio Engineers* (November, 1945): 743.; Davis, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I,* 50, 53.

Secretary of War went to the President and by June 1937, the Signal Corps received $200,000 in research funds for the next fiscal year.[300]

General Arnold, present at this test, was "satisfied with the potential that radar had demonstrated and pushed ahead hard for combat capability in that area."[301] On 12 July 1937, he delivered military specifications to the Signal Corps for a system with a 120-mile range. This request led to the SCR-270 and SCR-271, the former mobile, the latter fixed. They had a range of 100-150 miles, 75 miles for fighter size targets and approximately 2 miles and 4 degrees of error, sacrificing accuracy for range, thus meeting General Arnold's requirements.[302] They served as the early warning sets to the SCR-268, in much the same manner as with the German Freya-Würzburg concept discussed later. These radars served the US through World War II and into Korea.[303]

The Signal Corps developed radar despite the severe lack of funding through the 1937 demonstrations. Funds in 1937 were actually less than in 1936 even after diverting $75,741.74 to aircraft detection from other projects; other Signal Corps projects totaled $133,748.54. The Signal Corps asked for more funds, but the answer was to take the extra $40,000 out of other less important projects for FY36-38. Radar competed for funds with other developments that turned out to be very important in WWII. "The first field artillery and infantry walkie-talkies, the vehicular radio sets SCR-193 and SCR-245, a shielding system for suppressing radio interference in tanks, the sound powered microphone,

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300 Davis, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I*, 54.; Roger B. Colton, "Radar in the United States Army," *Proceedings of the Institute of Radio Engineers* (November, 1945): 743.

301 Dik A. Daso, *Architects of American Air Supremacy: Gen. Hap Arnold and Dr. Theodore Von Kármán* (Maxwell AFB, Ala.: Air University Press, 1997), 80-81.

302 Brown, *A Radar History of World War II*, 72.; Conn, *Guarding the United States and Its Outposts*, 62.; Roger B. Colton, "Radar in the United States Army," *Proceedings of the Institute of Radio Engineers* (November, 1945): 750-751.; Davis, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I*, 54.

303 Brown, *A Radar History of World War II*, 72.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 46-48,125.

the throat microphone," and various others. In the end, the funds allotted to research were less than the final cost of a single SCR-268.[304]

US geography necessitated mobile radar sets. Initially, the Air Corps' need for long-range detection drove the size of the SCR- 270 and SCR-271. Mobility was an added benefit, but deemed "paramount in the minds of planners, who had vast areas to defend and who thought in terms of shifting the detectors to this or that threatened area."[305] Despite this early desire for mobility, it took time for the US to realize the SCR-270s potential, which combined mobility and the ability to detect in range, azimuth, and elevation. It provided a tremendous capability and proved flexible in a mobile war. In May 1940, the Army officially adopted the SCR-270. Its mobility and size made it the early warning radar set of choice for the duration of the war.[306] By war's end, the Army received 788 SCR-270/271 radar sets.[307]

Clearly, the US was too large to build many fixed sites as the British had done. The British CH system used longer wavelengths requiring the large 240-350 feet radar towers surrounding Great Britain. The SCR-270 had a wavelength of nine feet and thus a proportional antenna size. The US was able to accomplish this reduction in size by introducing new vacuum tubes.[308] This initial use of vacuum tubes set the stage for microwave radar and hence smaller and more mobile radar sets.

One of the most important unintended consequences of the many radar experiments in the 1930s was a fortuitous experiment in November 1938 with the SCR-268, with General Arnold again present, that led to an expanded role for radar technology. During the experiment, a B-10

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[304] Davis, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I,* 34-35, 53-54.
[305] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 96.
[306] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 94, 96.
[307] Roger B. Colton, "Radar in the United States Army," *Proceedings of the Institute of Radio Engineers* (November, 1945): 751.
[308] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 128.

bomber blew off course over the Atlantic Ocean and engineers working with the SCR-268 vectored it back to its base. The Air Corps therefore saw that radar could also serve as a navigational aid.[309]

By December 1941, the Army possessed 580 radar models, SCR-268, 270, 271. Of those, 112 were SCR-270s with some on Hawaii, one of which detected the Japanese attack force. A command and control system to capitalize on the new capability, however, was almost non-existent.[310]

VHF Direction Finding (D/F) Equipment

Whereas radar was initially used to track enemy aircraft, VHF D/F equipment was used to track and control friendly aircraft. D/F Fixer stations located approximately 40-60 miles apart in an equilateral triangle provided the location of an aircraft by taking simultaneous bearings of the aircraft every minute and relaying these to the operations room. Pursuit aircraft were "equipped with an airborne receiver-transmitter set controlled by a push-button selector unit." This unit had four pre-set push-button channels; an operational control frequency, a common frequency, a homing frequency and a D/F frequency. It also generated an automatic signal every 15 seconds and synchronized to the clock in the control room to provide the controller a fix on his flight. This system allowed the controller to control and maintain awareness on four flights of aircraft.[311]

VHF, a line of sight system, had a limited range of 100 to 150 miles, necessitating a relay system to extend the range of operations. This was extremely useful when the system began to move away from a static defensive system to a mobile system on the move with an Army in

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309 Brown, *A Radar History of World War II*, 71-72.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 127.

310 Brown, *A Radar History of World War II*, 72-73.; Roger B. Colton, "Radar in the United States Army," *Proceedings of the Institute of Radio Engineers* (November, 1945): 740, 752.

311 AAFSAT Course Lecture, "VHF Control Net System," Call # 248.25-21, in the USAF Collection, AFHRA, Maxwell AFB AL.

the field. This mobile system consisted of three trucks with the necessary antennas, receivers, and transmitters. A D/F "Homer" Station provided the aircraft a beacon to home base by switching the receiver-transmitter set to the homing frequency. A mobile D/F station truck provided the same capabilities as fixed D/F stations, giving it the ability to replace a fixed site if the fixed site became inoperable. Mobility gave it the ability to eliminate dead areas in signal transmission due to terrain.[312]

Air Interception Radar

The British were the first to develop the idea of putting radar on aircraft.[313] Many factors explain why it was the British and not the Americans, or why airborne sets had not developed almost simultaneously as had ground radars. First, in the US, the SCR-268 program was so secret that ideas, problem solving, and application to new areas could not develop. Second, the British developed AI in response to a specific RAF need due to the immediate circumstances in which they found themselves. The US simply did not foresee the need for such diverse equipment.

In 1940, the US purchased a sample British AI set and air-to-surface vessel radar after a trip to England. By this time, the British had the Mark III with a range of two miles and the Mark IV with a range of four miles.[314] The Americans bought the Mark IV AI set. This led to the Air Corps testing its first AI by early 1941, the AI-10, to go into a modified A-20 "Havoc" bomber or the new P-61 Black Widow.[315] The AI-10 was a microwave design, designated the SCR-520. The British took it for their fighters because it proved to be a superior design.[316] The P-61

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312 AAFSAT Course Lecture, "VHF Control Net System," Call # 248.25-21, in the USAF Collection, AFHRA, Maxwell AFB AL.

313 Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 198.; Brown, *A Radar History of World War II*, 118.

314 "The Nightfighters," *Radar*, no. 8 (20 February 1945): 45.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 254.

315 Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 254.

316 Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 86, 248.

would take until 1944 to come off the assembly lines, so the AI-10 initially went into the A-20, subsequently designated the P-70.[317] It would be late spring 1942 before the Air Corps received the AI-10. Until then, it used the SCR-540, a variant of the British AI Mark-IV, in the P-70 (A-20G night fighter). Once the AI-10 became operational, the inferior SCR-540 became a training model.[318] The SCR-540 was obsolete by October 1942.[319]

Identification Friend or Foe

The Signal Corps was aware of two devices the British used; the "pip-squeak" and the more familiar IFF. The first "pip-squeak" sent a 15-second signal every minute over the command net.[320] The second was the more familiar IFF. [321] In mid-1940, the Air Corps requested from the Signal Corps a similar system to the British one used with CH. Initial tests followed the same concept and design as the British Mark I IFF, using a resonant rod of the same frequency as the radar along with the radar's antenna. They adopted a similar Navy project due to its superiority. It used an interrogator-responder on the ground, a transponder in the aircraft, and its own set of frequencies. This meant a single IFF set worked on any radar set since the IFF set was not tied to a particular frequency. The Americans called their system RR, or radio recognition.[322]

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[317] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 261.

[318] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 86, 247.; Brown, *A Radar History of World War II*, 118.; AAFSAT Course Lecture, "GCI-AI Team," January 1944, Call # 248.25-8, in the USAF Collection, AFHRA, Maxwell AFB AL.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 262.

[319] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 248.

[320] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 85.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 190.

[321] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 85.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 190.

[322] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 190-91.; Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 85.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 131.

The first IFF systems, the British Mark I and Mark II, had several deficiencies, spurring the United States to create its superior IFF system. The British devices required in-flight adjustments by the pilot to match the radar frequency. If the pilot forgot to tune the IFF or mistuned the frequency, no IFF return appeared on the fighter controller's scope. Additionally, the Mark II responded to German interrogations if the German radar tuned to the particular IFF frequency. The United States received its first AI, the Mark III in September 1940.[323]

The Tizard Mission

Tizard thought the US and Canada would be helpful on a technical and production level and felt working an arrangement to share technical secrets would be beneficial. There were many in Britain, including Watson-Watt and Churchill, who were against giving the US various scientific secrets, such as the cavity magnetron and the status of the UK's radar system. Although initially against it, once he became Prime Minister and with France fallen, Churchill became a supporter of the mission which occurred in September 1940. Regarding command and control, the Tizard Mission, officially called the British Technical and Scientific Mission to the United States, finally convinced the US Chiefs of Staff of radar's importance and now supported its rapid development.[324] Secondly, it sparked the cooperation between the government and research laboratories, such as the famous MIT radiation laboratory, modeled after the British AMRE.[325]

On a technical level, the visit provided the US immediate access to examine and replicate the Randall and Boot magnetron, which increased the power available by 1000 times,[326] and directly led to the development of powerful microwave radars. It also gave them AI-radar, which also

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[323] Brown, *A Radar History of World War II*, 130-31.
[324] Bowen, *Radar Days*, 150-158.; Clark, *Tizard,* 248.
[325] Bowen, *Radar Days*, 173.
[326] Clark, *Tizard,* 268.

made a tremendous impression since the US had no such device on the drawing board and the capability it brought to the command and control system.[327]

Conclusion

From November 1918 until December 1941, the United States Air Service/Air Corps focused mainly on developing a strategic bombardment doctrine in the context of air defense—it became the only way to acquire the large bombers necessary to execute the doctrine. The Air Corps, however, neglected air defense in terms of pursuit development and the means to command and control aircraft until 1939-1940. Even once radar became available, the Air Corps was slow in building equipment inventory, training, and developing a command and control system. Pearl Harbor is evidence of this neglect.

From the early 1930s, however, advocates discussed and argued for a command and control system. Organizationally, the idea of a unified air commander for certain operations (including air defense) became accepted, laying the foundation for the concentration and control of air power under a single air commander. The Air Corps also failed to solve the problems of aircraft detection or build the communication infrastructure for a proper command and control system. The Coast Artillery Corps served as the primary proponent for both an integrated command and control system and a method to detect aircraft. The SCR-268, a gun laying radar, became the first radar developed and the foundation for the Air Corps' longer-range radars. The processes of using observers and plotters originated from the Coast Artillery Corps' requirement to have advanced warning of incoming aircraft in order to maximize AAA effectiveness.

The Air Corps began developing its command and control organizational structure, processes, and technology once it became

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[327] Ibid, 271.

evident war was a real possibility. It also served as a way for the Air Corps to have a valid mission through the establishment of an Air Defense Command. This foundation provided the springboard for all future command and control development. The Air Crops created schools, developed or enhanced processes, and developed ground radar for air defense. It however did not have a formal process to explore technologies or guide the development of its command and control processes as did the UK.

As in the UK, almost no progress occurred in the realm of air-to-ground command and control during the interwar period despite being the only country in the world for most of the 1920s and 1930s to have dedicated ground attack squadrons. A robust command and control system failed to emerge. German success in Poland and then France spurred the US, as it had the UK, into building an air-to-ground command and control system. This system was remarkably the same conceptually to the German air-to-ground system. In both the development of an air-to-air and air-to-ground command and control system, war served as the spark necessary to force creation. In conclusion, ACTS thought in the 1920s and 1930s focused on the primacy of bombardment over other aspects of airpower, thereby crippling command and control development.

Chapter 4

Germany During the Interwar Period

Introduction

Germany, although hampered by the Versailles Treaty, developed many of the same doctrinal ideas as the UK and the US regarding strategic bombardment and the offensive nature of airpower. Germany spent the 1920's concerned about defense and despite allowed an aircraft reporting service in the terms of the peace treaty, it did not develop a robust air defense command and control system comparable to the UK. The prohibition on fighters may have been a factor, but the Luftwaffe did not actively look for technology to enhance early warning. It so focused on offensive operations that it blinded the Luftwaffe to the potential for development of a command and control system that might shift some of the balance of strength from the offense to the defense.

Despite having a very robust air defense system, probably the strongest in the world, and understanding the need for a command and control system, Germany did not have a fully integrated air defense command and control system comparable to the United Kingdom or even the US by the time it entered the war. Germany did have a process for early warning, reporting, and getting information to its AAA, but it failed to integrate already existing radar technology. Once bombs began to fall on Germany, the Luftwaffe moved to integrate radar into its system.

Critically, Germany lacked a formal process for thinking about technology regarding command and control. Scientifically, Germany had access to at least the same level of scientific capability as the UK. Perhaps much as with the US, the Luftwaffe focused on building the outward appearances and capabilities of an air force and neglected a critical supporting function such as command and control. Doctrine and technically advanced AAA capability may have also driven Germany to accept the solution it had instead of searching for a better one until needed.

Despite Germany believing the UK possibly possessed radar, it never conceived that the UK had a method for controlling aircraft. The Luftwaffe did not connect the idea of combining radar technology to improving air defense. The German Navy however did, but did not share the technology or concept until forced to do so. Having a system in place may have also helped Germany appreciate and understand how to attack Great Britain's command and control system.

Germany's air-to-ground system, while still evolving, was envied, copied, and made much more effective during the war. Its development was a natural outgrowth of German mobile warfare and rich combined arms heritage. Much as the UK's development of an air-to-air command and control system was the response to its military needs, Germany's air-to-ground command and control system was also a response to a military need, one based on doctrine.

The Political and Economic Situation

Germany's political history after the Great War is well known. The worldwide economic depression created immense social problems, hampered the military's growth, and set the stage for Hitler's accession to power.

After World War I, the German *Luftstreitkraefte* decreased from approximately 5,500 aviators on active duty and another 5,500 in training or conducting other air services[1] to almost zero overnight as it disbanded and complied with the Armistice and treaty provisions. General von Seeckt however, despite formally disbanding the *Luftstreitkraefte* on 21 January 1921, ensured "180 pilot officers,

[1] Georg Paul Neumann and John Everard Gurdon, *The German Air Force in the Great War* (London: Hodder and Stoughton Ltd., 1921), 51-52.

veterans of World War I…be accepted into the National Army."[2] This small number within the 100,000 man Army allowed by the Versailles Treaty served as the seed for a future air arm and assisted in circumventing the treaty provisions preventing the existence of an air force. By October 1933, it had 228 officers and 1600 NCOs; by the Luftwaffe's acknowledged existence in March 1935, it had 20,000 men, with 15,000 Officers and 370,000 NCOs by September 1939. Almost the entire senior officer corps comprised former army officers, as the initial transfer to build up the Luftwaffe drew mostly from the Army and some from the Navy.[3]

The Versailles Treaty's universal unpopularity in Germany led to attempts to circumvent its provisions by military and political leaders alike. A trade agreement with Russia on 6 May 1921 initiated economic and military talks, setting the stage for expanded cooperation between the two nations and leading to the Treaty of Rapallo on 16 April 1922. The treaty renounced war reparations to Russia, expanded trade, resumed diplomatic ties, and led to talks establishing the German flying school at Lipetsk from 1925-1933. On May 22, 1926, the Allies removed some aircraft production provisions, opening the door to German aircraft development.[4]

Soon after Hitler became Chancellor of Germany on 30 January 1933, he began expanding the Luftwaffe with a 1000 aircraft program, and each year thereafter increased military spending to rearm the Luftwaffe.[5] By March 1935, Adolf Hitler had renounced the Versailles

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[2] Richard Suchenwirth, *USAF Historical Studies: No. 160, The Development of the German Air Force, 1919-1939*, ed. USAF Historical Division Aerospace Studies Institute (Air University, Maxwell AFB, Alabama, June 1968), 2, 5.
[3] Great Britain, *The Rise and Fall of the German Air Force, 1933-1945* (London: Arms and Armour Press, 1983), 11, 28.; Germany, *Germany and the Second World War* (Oxford: Clarendon Press, 1990), 485-487.
[4] Hanfried Schliephake, *The Birth of the Luftwaffe* (Chicago: Regnery, 1972), 13, 23.; Suchenwirth, *The Development of the German Air Force, 1919-1939*, 11-13.
[5] Homze, *Arming the Luftwaffe: the Reich Air Ministry and the German Aircraft Industry, 1919-39*, 74-75.; Germany, *Germany and the Second World War*, 490.

Treaty. Later that year, Germany assessed its potential enemies as France, Poland, Belgium, and Czechoslovakia, meaning the possibility of a two-front war. To support its offensive operational doctrine and support the ground forces, the Luftwaffe embarked on a plan to build twin-engine bombers and dive-bombers. Fighter production was reduced to build those aircraft, requiring air defense to rely on AAA.[6] The plan was to raise aircraft output to 5,112 aircraft in 1936.[7] That same year, German troops reentered the Rhineland without opposition from other European powers. Lack of opposition emboldened Hitler to make plans for more territorial acquisitions. To support his plans the German military quickly expanded and modernized.

Germany accomplished this by violating the Versailles Treaty, which prohibited a German Air Force. The Versailles Treaty, Section III, Articles 198-202 contained the Air Clauses. The most damaging long-term effects to Germany were Articles 199 and 202, with Article 201 to a lesser degree. Article 199 prohibited maintaining air force personnel after October 1, 1919 and Article 202 required Germany to hand over "all military and naval aeronautical material." Article 201 prohibited the "manufacture and importation of aircraft, parts of aircraft, engines for aircraft, and parts of engines for aircraft" into German territory.[8] The consensus within Germany was that these articles intended to not only abolish military aviation, but to cripple German civil aviation and give the Allies access to German aviation technology and material.[9]

The year 1936 also saw the creation of the Luftwaffe General Staff on 1 August 1936 and the implementation of the Four-Year Plan in October 1936, intended "to make Germany as self-sufficient as possible."[10] On November 5, 1937, Hitler explained his expansion plan to

[6] Schliephake, *The Birth of the Luftwaffe*, 38.
[7] Homze, *Arming the Luftwaffe*, 103
[8] "The Versailles Treaty, June 28, 1919," (The Avalon Project at Yale Law School, 2008).
[9] Morrow, *German Air Power in World War I*, 160.
[10] Homze, *Arming the Luftwaffe*, 101, 142.

his military leaders. Aircraft production rates changed that same year and then again, in 1938 when Hitler directed a five-fold increase in the Luftwaffe's size.[11]

In 1938, despite material shortages, the Luftwaffe General Staff created a plan to grow the Luftwaffe from 11,800 to 45,700 airplanes by 1 April 1942. The 33,900 aircraft increase included 9000 bombers, 4300 fighters, 3500 heavy fighters, 200 ground support, 4000 transport, and 12,900 trainers, reconnaissance, and passenger aircraft. The plan also included the procurement of 47,200 AAA pieces ranging from 20mm to 105mm.[12]

In March 1938, Germany annexed Austria in the *Anschluss*, giving Hitler the confidence to take the Sudetenland, a German speaking area of Czechoslovakia. In an effort to avoid war and "attain peace in our time," Germany gained control of the Sudetenland through the acquiescence of other major European powers at Munich on 30 September 1938. In March 1939, Germany invaded Bohemia and Moravia, dismembering Czechoslovakia and in April 1939, Germany renounced the 1934 Polish-German non-aggression pact. In August 1939, Germany signed the Molotov-Ribbentrop Pact with the Soviet Union, effectively securing Germany's east flank for the 1 September 1939 invasion of Poland. On 1 September 1939, the Luftwaffe had 302 combat ready squadrons in 21 Groups. 90% of the 4093 available frontline aircraft were ready for operations.[13]

Britain and France, unable to prevent Poland's fall, finally reacted to Germany's aggression and declared war. In April 1940, to preempt Britain from controlling Norway, Germany seized Norway and Denmark, followed by an attack against Belgium, Holland, and France on 10 May

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[11] Homze, *Arming the Luftwaffe*, 151; Germany, *Germany and the Second World War*, 504.
[12] Homze, *Arming the Luftwaffe*, 151; Walter Grabmann, *USAF Historical Studies: No. 164 German Air Force Air Defense Operations 1933-1945 Vol 1,* ed. USAF Historical Division Research Studies Institute (Air University, Maxwell AFB, Alabama, 1956), 125.
[13] Germany, *Germany and the Second World War*, 503.

1940. By mid 1941, Germany had military forces in North Africa and Greece to help the struggling Italians. They had also invaded Yugoslavia. On the eve of Germany's invasion of the Soviet Union on 22 June 1941, Germany controlled almost all of Europe. On 11 December 1941, Germany declared war on the United States.

By 11 December 1941, German leadership had been preparing for war for over six years while the military had been engaged in war for the past two years. These years of preparation and warfare should have led to greater preparation in terms of weapons development and production. Germany should have also realized that maintaining control of such a vast amount of European territory would entail defending it, especially against the obstinate British. Controlling Europe and attempting to conquer the vastness of the Soviet Union placed an immense burden on industry and the military's ability to recapitalize, especially under a regime that did not place the country on a war footing until 1943. By then Germany's fate was sealed.

Organization

Airpower's Place in the Army

Even before the ink dried on the Versailles Treaty, Germany began circumventing the provisions forbidding it from having an air force or a general staff. The Versailles Treaty did not allow a General Staff, so the *Truppenamt* served as the German General Staff in disguise. With his 180 pilot officers, von Seeckt immediately began clandestinely building a future air force. The *Truppenamt*, established on 1 March 1920, contained the *Truppenamt* (*Luftschutz*), really the Air Organization and Training Office (TA (L)). The *Truppenamt* (*Luftschutz*) reported directly to the Chief of the Troop Office. One of Germany's greatest issues and fears during the 1920s was how to defend against a potential attack from Poland; hence, the immediate focus and attention to air power's air defense value. The Foreign Air Office located within the T3 (Foreign Armies Department) compiled information on, and evaluated, foreign air forces while the Air Technical Office fell under the Office for Weapons and Equipment (*Inspektion fuer Waffen und Geraet or InWG*) in the Army Ordnance Office (*Heereswaffenamt*) and followed foreign technology and developments.[14]

In 1925, the Air Organization and Training Office (TA L), still subordinate to the Chief of Army Command became T2 III (L), now devoted to organizational matters, acted "as the central agency for all matters pertaining to aviation." Sometime in 1926, the Air Organization and Training Office became known as T2 V (L), under the Training Inspectorate, and then in 1929 under the command of a General Officer. Since 1928, Branch T-2 VL of the *Truppenamt* had the responsibility for tactical air requirements. Before February 1933, responsibility lay with the Reich Minister of the Interior who worked with the state minister for interior on training and manning issues.[15]

Although the Defense Ministry explored consolidating military and civil aviation to eliminate duplication and save money, Hitler's ascension as Chancellor accelerated the process.[16] Possibly reading the political tealeaves, by early 1933 changes in the Air Force's structure were underway. On January 24, 1933, the Air Inspectorate separated from under the Weapon School Inspectorate, yet both remained under the *Truppenamt*.[17]

Hitler's assumption of power on 30 January 1933 and the creation of the Reich Aviation Commission, a Cabinet position, under Hermann Göring hastened the changes. On 8 February 1933, possibly to prevent the creation of an independent Air Force, especially with Göring now in

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[14] Suchenwirth, *The Development of the German Air Force, 1919-1939*, 6, 17.; Homze, *Arming the Luftwaffe*, 6.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 12a.; Robert Michael Citino, *The Evolution of Blitzkrieg Tactics: Germany defends itself against Poland, 1918-1933* (New York: Greenwood Press, 1987).

[15] Suchenwirth, *The Development of the German Air Force, 1919-1939*, 17-19.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 1, 12a.

[16] Homze, *Arming the Luftwaffe*, 48-49.

[17] Schliephake, *The Birth of the Luftwaffe*, 30.

charge of civil aviation, the services set aside their differences to create the central air operations staff under the name of *Luftschutzamt* (Air Defense Organization) as a part of the Reich Ministry of Defense, effective 1 April 1933. This merged all Army and Navy aviation, but left air equipment development to the Army Ordnance Office.[18] The *Luftschutzamt* became the *Luftkommandoamt* (Office of Air Command) after a *Reichsluftfahrtministerium* (Reich Ministry for Aviation, RLM) reorganization on 1 September 1933, putting Secretary of State for Air, Erhard Milch under the Air Ministry and Hermann Göring.[19]

The RLM replaced the *Reichskommissariat fur die Luftfahrt* (Reich Aviation Commission or Reich Inspectorate of Aviation) on 1 May 1933, becoming responsible for all aviation issues, with a subsection, which functioned as the Air Force General Staff. The *Luftwaffe*, originally called the *Reichsluftwaffe,* became an independent branch on 26 February 1935 and announced publicly on 1 March 1935.[20] The Army and Navy's apprehension about Göring's ambitions was well founded. As the Commander in Chief of the Luftwaffe beginning in 1935, he used his dual position to attain large sums of money for the Luftwaffe's expansion, giving the Luftwaffe a unique position among the three services.[21]

On 15 May 1933, the Air Defense Office moved from the Defense Ministry to the Air Ministry, removing air defense from Army control. Tactical control of AAA transferred from the corps area commanders to the new Luftwaffe, under the Reich Minister for Aviation on 1 April 1934. The Army continued to train and equip AAA units until 1 April 1935

[18] Suchenwirth, *The Development of the German Air Force, 1919-1939*, 46-47, 51; Schliephake, *The Birth of the Luftwaffe, 30.*; Homze, *Arming the Luftwaffe*, 49.
[19] Schliephake, *The Birth of the Luftwaffe*, 31.
[20] Germany, *Germany and the Second World War*, 481-482.; Schliephake, *The Birth of the Luftwaffe*, 34.; Great Britain, *The Rise and Fall of the German Air Force, 1933-1945,* 33.
[21] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 10a, 13-15, 23., Suchenwirth, *The Development of the German Air Force, 1919-1939*, 57.

while the Luftwaffe continued to control all aircraft and the Aircraft Reporting Service (ARS).[22]

Thinkers and Theorists

Lieutenant General Walter Wever, the first Luftwaffe chief of the general staff from September 1933 to June 1936, was the leading German air power theorist until his premature death. Despite the well-known concept that no general staff officer's name appears on doctrinal manuals and documents, he is known to have played a critical and driving role in the development of the doctrinal manual entitled *Dienstvorschrift 16 "Luftkriegfuehrung,"* or L. Dv 16. The manual reflected his thoughts on airpower.[23]

General Wever believed in "strategic bombing as the primary mission of the air force." However, he did not say the air force could win a war alone; rather it could play a decisive role in conjunction with the other services. Despite no German translation of *The Command of the Air* available until 1937, Wever was clearly familiar with Douhet and either read the work in another language or the smaller articles that eventually made up the book. Overall, he believed in Douhet's concepts, yet he rejected some of the Italian theorist's propositions and initially opposed an independent air service. He believed an air force had two jobs; home defense and defeating the enemy. Both required air superiority. Home defense required the integration of AAA, searchlights, observers, fighters, and civil defense, while defeating the enemy did not necessarily mean their fielded forces such as the army or navy. It also meant attacking means of production and the people's will.[24]

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[22] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 10a, 13-15, 23.; Suchenwirth, *The Development of the German Air Force, 1919-1939*, 57.; Schliephake, *The Birth of the Luftwaffe*, 31.
[23] James S. Corum, *The Luftwaffe: Creating the Operational Air War, 1918-1940*, Modern War Studies (Lawrence: University Press of Kansas, 1997), 134.
[24] Matthew Cooper, *The German Air Force, 1933-1945: An Anatomy of Failure* (London: Jane's, 1981), 65.; Corum, The Luftwaffe: Creating the Operational Air War, 1918-1940, 135-139.; Hooten, *Phoenix Triumphant,* 88.

He believed defenses could be powerful, although not invincible; they could not cover everything and be strong everywhere. The cost in terms of aircraft was too great. The best defense therefore was a strong offense; thus, "the creation of a heavy-bomber force was regarded as a culmination of a mature, well balanced effective air force." Part of a well-balanced air force supported ground operations, but only at the decisive points, which usually meant operating in support of mobile mechanized forces. He believed only ground forces involved at the decisive point should expect air power support.[25]

Doctrine Concepts and Thought

As in America, doctrine existed in Germany in two forms; de jure and de facto. Multiple manuals captured the techniques and practices developed from the end of WWI until the mid-1930s. Lessons from the Spanish Civil War added realism to German operational thinking.

Army Regulation 487: Leadership and Battle with Combined Arms, released in two parts, 1921 and 1923 and updated regularly until 1933, resulted from an extensive review and study of air operations. The 1921 portion divided air forces in terms of observation and fighting. The Army possessed organic air units and continued to do so until the Luftwaffe's emergence in 1933. Attacking enemy aviation, through offensive action, gained air superiority. The Luftwaffe viewed "defensive screens or sector barriers as impossible." A Reichswehr Air Operations Manual from the mid-1920s specifically stated, "the primary mission of the fighters is to shoot down as many aircraft as possible to provide our own aerial forces with freedom of movement."[26]

The 1923 portion discussed the bomber's vulnerability and how night attacks allowed deeper penetration into enemy territory. From an

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[25] Caldwell and Muller, *The Luftwaffe over Germany*, 19.; Cooper, *The German Air Force, 1933-1945*, 66.; Corum, The Luftwaffe: Creating the Operational Air War, 1918-1940, 139.

[26] James S. Corum and Richard Muller, *The Luftwaffe's Way of War: German Air Force Doctrine, 1911-1945* (Baltimore, Md: Nautical & Aviation Pub., 1998), 73-75, 88-90

air defense perspective, the manual described the possibility of intercepting enemy aircraft, but only if the intercepting forces used radios for communicating the exact position of the enemy and stayed in constant contact to pass information. "On the ground, flying officers posted far forward (air defense officers) keep the flying units continuously informed of the aerial battle situation." They used radios to pass the information. Information from spotters, AAA, and searchlights also enhanced awareness. The manual also discussed the need for a unified command for air defense, usually under a battalion command, under the artillery division commander.[27]

In May 1926, the German air staff released the *Directives for the Execution of the Operational Air War,* built on the ideas in *Army Regulation 487: Leadership and Battle with Combined Arms*. It envisioned an air force for use against not just ground forces, which had aircraft under its direct control, but also against population centers and industry to affect moral, the economy, and weaken the enemy's will. Air superiority enabled other operations and it could "have a decisive influence over the ground battle." However, as the sky was too big, air superiority was temporary and fleeting, requiring constant effort to gain and maintain.[28]

German thinkers viewed air power as offensive by nature, so the pure defense appeared out of character. Defense provided no advantage but mobility, surprise, and concentration. It also served to make bombing and reconnaissance more difficult. However, escorts could assist bombers in overcoming defenses. Most importantly, the directive called for a "single unified organization for home air defense" reporting to a single commander as it carried out several missions. These included Observation (by the ARS), Fighting Aircraft (the Air Defense), warning of

[27] Ibid, 77-80.
[28] Ibid, 93, 96, 99-100, 102.

business and populace (the Alert Service), and protection from enemy observation (the Camouflage Service).[29]

L. Dv 16 was the *Luftwaffe's* seminal doctrinal manual, guiding the *Luftwaffe* through WWII with only minor modifications in 1940. L. Dv 16 confidently asserted, "The mission of the armed forces in war is to break down the will of the enemy," which is embodied not only in the enemy armed forces, but also in enemy production and industrial capacity. The armed forces needed air superiority as a prerequisite for other operations. Air superiority required constant attention to gain and maintain, and required fighting the enemy air force from the start of the campaign.[30] This concept was entrenched early in German doctrinal thought and mirrored the British concept of the best defense is a strong offense. For example, Lieutenant Colonel Hellmuth Felmy submitted a report in February 1932 arguing for the creation of an air force focusing heavily on bombers as the main arm in order to knock out the enemy's air force. He too believed the bomber would always get through.[31]

The manual stressed that an enemy will attack the homeland, so the importance of defense was in offensively attacking the enemy air force and hitting them before they reached the air defense area. This assumed early detection. Limited resources and the German tradition of concentration at the *Schwerpunkt* contributed to this viewpoint. The manual gave both AAA and fighters the responsibility for air defense, but gave AAA the key defensive role. It also gave an offensive role to fighters.[32] Nonetheless, fighters and AAA should be organized under a unified commander, under a command ARS, with an effective

[29] Ibid, 99-100, 110.
[30] Corum and Muller, *The Luftwaffe's Way of War,* 119-120, 122, 130, 133-141.; *L. Dv. 16, The Conduct of Aerial Warfare*, (Ernst Siegfried Mittler and Son, Publishing House, Berlin, 1940), Call # 519.601B-4, in the USAF Collection, AFHRA, Maxwell AFB AL.
[31] Homze, *Arming the Luftwaffe, 1919-39*, 34.
[32] Grabmann, *USAF Historical Studies: No. 164 German Air Force Air Defense Operations 1933-1945 Vol 1,* 36, 38, 40, 63a, 64, 67a, 90, 160.; Corum, *The Luftwaffe: Creating the Operational Air War, 1918-1940*, 163.

communication net for control, and close cooperation between fighters, searchlights, and AAA.[33]

Air-to-Ground Operations

Although relatively primitive air-ground coordination began in WWI, modern German air-ground coordination development began during the Spanish Civil War. During the war, General Wolfram von Richthofen developed a system to direct air strikes using air signal liaison detachments with air controllers attached to forward units to direct "approaching air units to specific targets difficult to detect from the air, using radio instruments in forward observer posts for the purpose."[34]

Because Air Signal Corps personnel "did not have adequate tactical knowledge to direct an air strike properly" and the manner of employing the signal equipment at forward points disconnected them from the Army HQ, the Luftwaffe "established special forward air control detachments to direct air strikes from the ground." Information flowed from the air control detachments via radio. Controllers observed the battle, made radio contact, and directed aircraft to the target.[35]

Two command structures existed for operations with the Army. The Koluft (*Kommandeure der Luftwaffe*), located at Army HQ to command short-range reconnaissance and keep the Luftwaffe command informed; and the Flivos (*Flieger Verbindingsoffiziere*). Flivos were flyers with communications teams attached by the Fliegerkorps to army corps HQ and panzer/motorized divisions. They resided under Luftwaffe Command and kept headquarters informed of Army events, such as the status of the front line, safety line, and overall situation, but could not

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[33] Corum and Muller, *The Luftwaffe's Way of War,* 152-155.; Deichmann, *USAF Historical Studies: No. 163 German Air Force Operations in Support of the Army*, 31.

[34] Paul Deichmann, *USAF Historical Studies: No. 163, German Air Force Operations in Support of the Army*, edited by Littleton B. Atkinson, USAF Historical Division Research Studies Institute (Air University, Maxwell AFB, Alabama, 1962), 133.; Cooper, *The German Air Force, 1933-1945*, 60; Richard Muller, *The German Air War in Russia* (Baltimore, Md: Nautical & Aviation Pub. Co. of America, 1992), 18-19.

[35] Deichmann, *German Air Force Operations in Support of the Army*, 133.

order strike missions. Ordering strike missions rested with the Luftwaffe air corps and division commanders, normally co-located with the Army HQ. The Army only assigned tasks for the air units under them, but the Luftwaffe was responsible for execution. On the front line, they resided in armored vehicles with radios, directed fighters to the target, passed them any changes, weather data, and the ground situation to include enemy defenses. Armored units stressed "close liaison with the air force is essential" for success and if air-ground action was likely to occur, they needed air liaisons officers at Armored Division HQ with an air signals section. The Luftwaffe had to know the targets, timing, armored movements, and target priorities. Marking positions occurred with panels, colored smoke, and flags. Finally, the best coordination occurred between the army and air force when the two HQs were co-located.[36]

The Luftwaffe gave operational control of the *Aufklaerungsgruppe (Heer)*, consisting of the *Nahaufklaerungsstaffeln* (corps squadrons) and *Fernaufklaerungsstaffeln* (long-range reconnaissance squadrons) to the Army, but continued to coordinate fighter-bomber support. The Army also wanted control of *Kampf-* and *Stuka-gruppen*. The Luftwaffe resisted.[37] Mirroring the views prevalent in other Armies, the German Army expected all airpower to directly support their operations. Limited airpower resources, however, forced a change and "in 1942 the Luftwaffe headquarters assigned under army commands were deactivated, and their missions were taken over by the headquarters of the operational air force," in order "to economize in staffs and manpower." Now army group

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[36] James S. Corum, *Wolfram von Richthofen: Master of the German Air War* (Lawrence, Kan: University Press of Kansas, 2008), 159, 162.; Deichmann, *German Air Force Operations in Support of the Army*, 16-17, 128,134.; The German Air Force Post Hostilities Course, "The German Air Force," by Lt Col D. M. Pearson, 1944, Call # 512.6314B, p. 12, in the USAF Collection, AFHRA, Maxwell AFB AL.; Translation, "Development of the German Ground Attack Arm and Principles Governing Its Operation up to the End of 1944, 8th Abteilung, 1 December 1944, Call # 512.621 VII/14 p.12, in the USAF Collection, AFHRA, Maxwell AFB AL.; "The German Armored Division," *Military Intelligence Service Information Bulletin No, 18* (War Department, Washington, D.C. June 15, 1942), Call # 168-607-30, pp. 8, 41, in the USAF Collection, AFHRA, Maxwell AFB AL.

[37] Hooten, *Phoenix Triumphant*, 100.

headquarters and army headquarters only had liaisons attached to them rather than entire aviation units.[38]

Exercises and Maneuvers

Germany entered into an agreement with Russia to conduct military training in Lipetsk, Russia starting in the summer of 1925 due to the provisions of the Versailles Treaty. The agreement allowed Germany to build an air force in concealment (if only on a very small scale), away from the prying eyes of international monitors. Only a few civilian flying schools existed, but not enough to build a large base of qualified pilots needed for a future air force. Lipetsk also served as a place for the air force to test equipment and procedures. A multitude of exercises occurred from 1925 to 1933, mainly focusing on direct air support operations. The exercise in 1932 specifically focused on "modes of attack used against bombers operating in daylight." The school closed in September 1933.[39]

Under treaty constraints, air defense exercises focused on processes and civil defense. The largest air raid exercises since WWI took place in East Prussia in 1932. It tested the ability to determine direction and targets of incoming raiders.[40] Only in 1933, after Hitler's rise to power, did visible exercises occur. In keeping with the doctrinal thought of offensive air power, the Wehrmacht war games in the winter of 1933-1934, while small, focused on bombing and concluded a "bomber fleet alone could not eliminate hostile air forces quickly enough and that Germany's exposed position urgently required a strong air defense in the form of fighter units and flak artillery."[41]

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[38] Deichmann, *German Air Force Operations in Support of the Army*, 17-19.

[39] Schliephake, *The Birth of the Luftwaffe*, 14-21.; Suchenwirth, *The Development of the German Air Force, 1919-1939*, 28.

[40] Robert Michael Citino, *The Path to Blitzkrieg: Doctrine and Training in the German Army, 1920-1939* (Boulder, Colo: Lynne Rienner Publishers, 1999), 207-208.

[41] Germany, *Germany and the Second World War*, 490.

The first large scale exercise, the Reichswehr Winter War Games in November 1934, centered on France invading Germany. The Luftwaffe focused first on destroying the air forces, then the ground forces. Despite success, bombers incurred 80% loss rates and the exercise highlighted the need for better air-to-ground cooperation.[42] The exercise also had minimal AAA and fighter cooperation for defensive purposes.[43]

Exercises grew bigger and more complex in 1935. An exercise in September 1935 included 24 squadrons,[44] while the November 1935 exercise was a two-front war scenario. The Luftwaffe gave the Army 25% of its fighter force, and as a result was unable to gain control of the air or destroy the enemy air force. Once the Luftwaffe concentrated its effort on destroying the enemy air force, success followed. Dive-bombing proved effective at destroying communications infrastructure.[45] Also, no night operations occurred.[46] Finally, a wargame study found the Luftwaffe inadequately prepared for a two-front war.[47]

Multiple exercises occurred in 1936. The armor-air exercise, called the *Grosse Herbstuebung* ("Great Fall Exercise"), did not go well, highlighting issues with communications to including transmitting reports and reconnaissance information. Even Heinz Guderian did not yet grasp how to integrate air and armor.[48] Luftkreiskommando II, near Berlin, conducted a fighter searchlight test, leading to another exercise in the summer of 1937. These tests occurred with and without searchlights

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[42] Hooten, *Phoenix Triumphant*, 88, 99-100.; Corum, *The Luftwaffe: Creating the Operational Air War, 1918-1940*, 152.
[43] Gebhard Aders, *History of the German Night Fighter Force, 1917-1945* (London [etc.]: Jane's Pub. Co., 1979), 9.
[44] The German Air Force Post Hostilities Course, "The German Air Force," by Lt Col D. M. Pearson, 1944, Call # 512.6314B, p. 4, in the USAF Collection, AFHRA, Maxwell AFB AL.
[45] Hooten, *Phoenix Triumphant*, 100.
[46] Aders, *History of the German Night Fighter Force,* 9.
[47] Germany, *Germany and the Second World War*, 501.
[48] Muller, *The German Air War in Russia,* 18.; Corum, *The Luftwaffe: Creating the Operational Air War, 1918-1940*, 234.; The German Air Force Post Hostilities Course, "The German Air Force," by Lt Col D. M. Pearson, 1944, Call # 512.6314B, p. 4, in the USAF Collection, AFHRA, Maxwell AFB AL.

and included an experimental Freya, detecting aircraft at 50-60 miles (80-100 km). [49]

Another exercise held 20-25 September 1937 evaluated the ARS organization and the existing commercial communications grid, finding them both adequate, but still needing improvement. The exercise highlighted several items. First, information must move rapidly and on time. Slow information meant the *Luftschutzwarnzentrale* (Air Warning Protection Center) did not have enough information to make decisions to launch or place aircraft on alert. Second, the exercise highlighted the need for the *Luftschutzwarnzentrale* to have a complete "air picture," both near and far. Third, aircraft tracking was not good, personnel were poorly trained, organization and processes required refinement, and the telephone system did not perform well. Wireless radio performed well and deemed necessary to improve communications and provide redundancy. Finally, the exercise experimented with dividing areas into sectors and subsectors to improve efficiency.[50]

A November 1937 report highlighted the possibility of night fighting against long-range enemy airbases and for defensive purposes. It also commented on the overall poor state of the existing fighter defense system, especially the slow and cumbersome reporting system.[51] Air-ground integration however proved effective.[52]

Throughout 1938, the Luftwaffe continued to conduct numerous air defense exercises, testing the aircraft warning system, AAA, and fighter coordination. The connectivity between *Flukos* in the cities and warning posts at the border worked well to inform civilians of incoming

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[49] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 12, 14, 29a, 30, 49, 129, 227.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2,* 267.

[50] *1937 Exercise*, NARS T321/Reel 10/Frame 4747773, in the USAF Collection, Fairchild Library, Maxwell AFB AL; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 12, 14, 29a, 30, 49, 129, 227.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2,* 267.

[51] Aders, *History of the German Night Fighter Force,* 9-10.; Hooten, *Phoenix Triumphant,* 172.; Corum, *The Luftwaffe: Creating the Operational Air War, 1918-1940*, 234.

[52] Citino, *The Path to Blitzkrieg*, 241.; Corum, *The Luftwaffe: Creating the Operational Air War, 1918-1940*, 234.

raids. Overall, the Luftwaffe deemed these exercise successful as it assessed the aircraft warning system to be well organized.[53] Coupled with the Spanish experience through 1939, these exercises validated the use of a motorized ARS equipped with radios, resulting in an air district signal battalion having a motorized aircraft reporting company by the spring of 1940.[54]

Events Around the World

Experience in Spain for close liaison and coordination between the Luftwaffe and the Army led to the creation of a special headquarters staff call the *Fliegerfuehrer zbV (zur besonderen Verfugung)* led by Generalmajor (Brigadier General) von Richthofen to work "out guide-lines for the organization, training, and operation of ground-attack formations on the basis of the experience gained in Spain." This organization developed many of the tactics and techniques of close air support.[55]

Germany learned several lessons from its experience in the Spanish Civil War. These included learning that the side holding air superiority held the initiative. Even with air superiority, bombers required fighter escort because bombers were very vulnerable to fighters. Germany had earlier identified the need for an escort fighter, a requirement already issued on 10 August 1932. The Spanish Civil War reaffirmed the assessment and the Germans therefore trimmed the bomber-fighter ratio from 3:1 to 2:1 under the 1938 plan to increase the fighter force.[56]

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[53] *1938 Exercise*, NARS T321/Reel 10/Frame 4747773, in the USAF Collection, Fairchild Library, Maxwell AFB AL

[54] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 12, 14, 29a, 30, 49, 129, 227.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2,* 267.

[55] Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 14.; Schliephake, *The Birth of the Luftwaffe*, 44.; Corum, *The Luftwaffe: Creating the Operational Air War, 1918-1940*, 223.

[56] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 79-80, 123.; Karl Drum, *USAF Historical Studies: No. 150 The German Air Force in the Spanish Civil War*, USAF Historical Division Research Studies Institute (Air University, Maxwell AFB, Alabama,1957), 199.; Corum, *The Luftwaffe: Creating the Operational Air War, 1918-1940*, 196-197, 222.; Hooten, *Phoenix Triumphant*, 109, 143.

Air defense proved as important as offensive fighter operations. Effective defensive operations forced Nationalist bombers to operate at night. From August 1936 to October 1938, 335 enemy aircraft were destroyed; 277 by aircraft and 58 by AAA. The Germans also assessed the difficulty of producing a lasting impact on enemy air installations and destruction of aircraft at airfields.[57]

Air Defense

Several factors encouraged Germany to think defensively immediately after World War I. First, Germany's strategic situation required a defensive posture. The Versailles Treaty had reduced Germany's military to 100,000, and prohibited an Air Force, but allowed limited AAA forces, leading to a heavy reliance on AAA for air defense. Second, hostile states surrounded Germany, especially Poland. Most German military planning throughout the 1920s revolved around fighting a defensive war against Poland.[58] Germany looked to aircraft to help its ground forces in such a war.[59] Third, defensive thought flourished in the 1920s mainly due to the limited range of aircraft, necessitating zone defense. In 1933, fighter radius was limited to 90 miles, leading to a 1937 Luftwaffe request for fighters with increased ranges. The limited fighter range of countries surrounding Germany meant Germany did not think the interior of Germany vulnerable to attack. It also meant Germany would need many fighters to defend its own borders. This technological limitation reinforced doctrinal thinking regarding offensive action being the best defensively.

By the early 1930s, military reforms, slightly improved fighter range, Hitler's rise to power, and Germany's historical need to conduct swift operations against multiple enemies moved Germany toward an

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[57] Schliephake, *The Birth of the Luftwaffe*, 43.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 79-80, 123.; Hooten, *Phoenix Triumphant,* 133.

[58] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 2-4, 12, 26a, 28, 93.; Citino, *The Evolution of Blitzkrieg Tactics.*

[59] Schliephake, *The Birth of the Luftwaffe*, 14. Citino, *The Evolution of Blitzkrieg Tactics.*

offensive doctrine. In this, Germany was "guided by a strategic concept of aiming to smash their respective adversaries separately by annihilating their armed forces in short campaigns."[60] Douhet's writings strongly influenced the Luftwaffe, naturally fitting Germany's offensive warfare style.[61] The Luftwaffe sought to destroy the enemy air force offensively through the destruction of the enemy bomber force at their home base. This required fewer fighters devoted to air defense, and did not tie the Luftwaffe to the Wehrmacht.[62] By 1937, as in the United States and Britain, fighters and artillery were below bombers in stature. Luftwaffe *Dienstvorschrift 16 "Luftkriegfuehrung"* released in 1936 expressed these ideas clearly.[63]

On 1 April 1934, Germany created six Air Service Commands with another added on 1 April 1937. This served as a transitional solution as the Luftwaffe moved from a secret to an open organization. By early 1937, seven Air Regional Commands, *Luftkreiskommandos*, existed.[64] Air district commands (*Luftgaue*), created in early April 1936, provided logistics and airfield support, and eventually realigned with corps command areas (*Wehrkreise*) in October 1937.[65]

On 4 February 1938, the Luftwaffe reorganized seven Air Regional Commands into three Luftwaffe Group Commands (*Luftwaffengruppenkommandos*), Air Command Eastern Prussia, Naval Air Command, and Air District Command I over Koenigsberg with air

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60 von Rohden, *European Contributions to the History of World War II, 1939-1945; The War in the Air. Reich Air Defense, 1939-1945; A Strategic-Tactical Survey*.

61 Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 19.

62 von Rohden, *European Contributions to the History of World War II, 1939-1945; the War in the Air. Reich Air Defense, 1939-1945; a Strategic-Tactical Survey*.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 21.

63 Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 21, 29, 85.

64 Suchenwirth, *The Development of the German Air Force, 1919-1939*, 66, 68. ; Hooten, *Phoenix Triumphant,* 102.

65 Corum, *The Luftwaffe: Creating the Operational Air War, 1918-1940*, 157.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 131a.

districts under them.[66] Operational units fell under the Luftwaffe Group Commands.[67] A second reorganization quickly followed on 1 August 1938 combining the air district commander and the senior district AAA officer, effectively giving the Air District Commands control of AAA and fighters for air defense. This move was in line with Luftwaffe doctrine outlined in L. Dv 16. Rather than seen as an effort to improve air defense, this reorganization raised the ire of many fighter units because it seemed to make the fighter a defensive weapon. Several fighter wing commanders, in line with Luftwaffe doctrine, viewed attacking enemy bombers at their bases as the best method of ensuring security.[68] Additionally, older Army or AAA officers led most Air Districts and fighter personnel did not want to be under their control.[69] This reorganization created a clear separation between offensive and defensive operations.[70] On 1 April 1939 the Luftwaffe Group Commands were renamed Air Fleet Commands (*Luftflotten*). *Luftgaus* (Air Districts) under Air Fleets did administrative work while Air Divisions (*Fliegerdivision*), later called Air Corps (*Fliegerkorps*) conducted operational work.[71] The Luftwaffe began the war with this organizational structure.

Aircraft Reporting Service

Originally, the Versailles Treaty did not allow for an ARS, but the 22 May 1926 Paris Agreement for passive air defense removed the restriction. Air defense, especially passive methods such as smoke,

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[66] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 132-33.; Schliephake, *The Birth of the Luftwaffe,* 44.; Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 34.

[67] Suchenwirth, *The Development of the German Air Force, 1919-1939*, 68-69.

[68] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 62, 97-99, 132-33.

[69] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2,* 239.

[70] Suchenwirth, *The Development of the German Air Force, 1919-1939*, 69.

[71] Suchenwirth, *The Development of the German Air Force, 1919-1939*, 68-69. ; Great Britain, *The Rise and fall of the German Air Force, 1933-1945,* 37.; "The German Air Force in Maps and Diagrams 1939-43," *Air Publication 3038* (November, 1943), Call # 512.6314T, p. 66, in the USAF Collection, AFHRA, Maxwell AFB AL.; The German Air Force Post Hostilities Course, "The German Air Force," by Lt Col D. M. Pearson, 1944, Call # 512.6314B, p. 5-9, in the USAF Collection, AFHRA, Maxwell AFB AL.; *Handbook on German Military Forces, War Department Technical Manual TM-E 30-451* (War Department, 1 March 1945), Call # 512.6314U v1, pp. X-1 – X-6, in the USAF Collection, AFHRA, Maxwell AFB AL.

camouflage, and the ARS, were taken very seriously because it was the best way to leverage a resource-constrained organization, giving it one of the highest priorities within the 100,000 man Reichswehr. Throughout the late 1920s and 1930s, the ARS relied heavily on volunteers and reservists, but still managed to improve training, grow, and improve the overall air defense system.

The ARS's mission, outlined in a 12 May 1937 directive, included providing estimates of the air situation through timely and speedy reporting of aircraft location using detachments located at 50-60 mile wide intervals and air observation posts located 6-7 miles apart. Originally, the Air Raid Precaution Officer controlled the ARS, falling under the corps commanders. When AAA moved from Army to Luftwaffe control on 1 April 1934, the newly created Luftwaffe Administrative Area Headquarters replaced the Air Raid Protection Officers. In the zone of operations, the Luftwaffe commanding officer attached to the army headquarters controlled the ARS, although field armies could have ARS companies assigned to them to cover gaps on their flanks. In the interior zones, the air district commanders controlled the ARS. The ARS finally moved to the Air Signal Corps in May 1938, which had responsibility for the observer corps, intercepted enemy signals, and operated the radar posts.[72]

Planning for War

In the midst of organizational change, Germany began preparations for war. While exercises validated many concepts, war solidified them. Analysis deemed the air defense structure and the material means to support the structure effective and sufficient. This analysis proved false and deadly once war began. Even after attacking France, learning the details of the British air defense system during the

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[72] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 29a, 129-31.; The German Air Force Post Hostilities Course, "The German Air Force," by Lt Col D. M. Pearson, 1944, Call # 512.6314B, p. 14-16, in the USAF Collection, AFHRA, Maxwell AFB AL.

Battle of Britain, and of pending operations against the Soviet Union, German air defense preparations still lacked urgency. Fighter, radar, AI, and IFF production did not meet the required demand for offensive operations nor did it meet air defense needs.

When Germany reoccupied the Rhineland in 1936, Germany had a three to one bomber to fighter ratio in keeping with its offensive doctrine. By 1 April 1937, the ratio shrank to two to one as defensive planning and political desires to show the Luftwaffe to the world began to unfold. Increased awareness of the need to protect vital industry as war loomed, led General Albert Kesselring, Chief of the Luftwaffe Command staff, to order on 28 April 1937 a night fighter defense exercise with and without searchlights. During the exercise, air defense fighters marshaled in an area behind the searchlights. Once the searchlights detected the enemy, fighters entered the zone and attacked the enemy, usually from the rear. This zone was forward of the AAA zone allowing the fighter to attack first and AAA to engage any aircraft not shot down. Day fighting had integrated zones because visual identification was less of a problem for AAA during the day.[73]

Germany created an Air Defense Zone West (*Luftverteidigungszone*) in 1938 to mirror the West Wall, placing AAA from the German border to the Elbe River.[74] The zone, between 12-60 miles in depth depending on the area, had AAA strategically placed to ensure enemy aircraft endured at least 5 minutes worth of exposure.[75] In the same year, the Luftwaffe became responsible for air defense from the Swiss border to Ostfriesland, with the Navy responsible for the islands of Borkum, Helgoland, and Sylt.[76] By 1939, Air Defense Command did not think a serious threat to

[73] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 54a, 84, 95-96.
[74] von Rohden, *European Contributions to the History of World War II, 1939-1945; the War in the Air. Reich Air Defense, 1939-1945; a Strategic-Tactical Survey*.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 109.
[75] Hooten, *Phoenix Triumphant*, 163.; Cooper, *The German Air Force, 1933-1945*, 56-58.
[76] Harry von Kroge, *GEMA: Birthplace of German Radar and Sonar* (Bristol, [England]; Philadelphia, PA: Institute of Physics Pub., 2000), 87.

Germany existed. The Czech seizure and Austrian Anschluss gave more security assurances coupled with Britain and France's failure to act against Hitler's bold actions since 1936. Despite a perceived lack of threats, the first night fighter groups created in 1939 quickly became day fighter groups once war began in Poland due to a shortage of fighter aircraft to fulfill both roles.[77]

Germany made no plans for a fighter control system; instead, it relied mainly on AAA for defense, thinking it sufficient. German AAA effectiveness led to the belief that AAA technology and performance would continue to grow and outperform aircraft. During WWII, Germany planned to use 600 rounds per aircraft, but in reality required 3,400 heavy shells to down one aircraft. AAA came under Luftwaffe control in 1935 and by 1939, AAA had 107,000 men, 2000 heavy guns, 6700 light and medium guns, 3000 searchlights. Other shortcomings included plotting equipment, sound equipment, and radars. At the start of the war, only eight Freya radars between Holland and Denmark existed.[78]

Processes

Unlike the UK, Germany did not build an integrated command and control system and the robust processes required. However, it did have basic procedures in place before September 1939.

The Air Spotter Service comprised of trained personnel equipped with special observation and audio equipment served the same purpose as the Observer Corps in the UK. They transmitted enemy aircraft location, time, type, number, direction, altitude, and nationality via radios and telephone, plotted the track data at a central headquarters and passed the information to fighter controllers. Tracking aircraft assisted finding enemy aircraft, much like those used during British

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[77] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 97, 181.

[78] Cooper, *The German Air Force, 1933-1945*, 56-58.; Aders, *History of the German Night Fighter Force, 1917-1945,* 7.

exercises. A flying command post for leadership with radios to transmit information also existed.[79]

A rather rudimentary control capability developed after the results of the summer 1937 exercise, whereby a fighter flew to a standby zone just behind an illuminated zone and searchlights assisted positioning the fighter to find the inbound aircraft and attack. FLAK could not fire into the night fighting zones without orders from night fighting district commanders. However, no permanent night fighting units existed before the war.[80] During the day, a fighter relied on the latest information provided by observers and listening devices.

Germany had a basic command and control system to support air-to-ground operations, but operations in Poland and later France helped refine and enhance the basic system, but even then, Germany never integrated radar into their offensive operations, as did the Allies.

Technology

Listening Devices

Germany utilized older dual sound locator devices, called *Doppelrichtungshoerer,* (*DRH*) since 1917 and into WWII. Most devices in WWII however were of the four-funnel type called *Ringtrichterrichtungshoerer*, (*RRH*). This was the equivalent of the American and British trumpet designs. It was accurate to 2 degrees and 12km range. Like all sound locators, the German models suffered the same drawbacks; limited range, lag, weather dependent, listener capability dependent, and less likely to detect as aircraft began to operate at higher attitudes. Nonetheless, German had 5,559 of these trumpet sound locaters in use as late as August 1944.[81]

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[79] Corum and Muller, *The Luftwaffe's Way of War*, 81, 93-94.; *Handbook on German Military Forces, War Department Technical Manual TM-E 30-451* (War Department, 1 March 1945), Call # 512.6314U v1, pp. X-11, in the USAF Collection, AFHRA, Maxwell AFB AL.

[80] Aders, *History of the German Night Fighter Force, 1917-1945,* 11.

[81] Werner Müller, *Sound locators, fire control systems, and searchlights of the heavy Flak* (Atglen, PA: Schiffer Pub. 1998), 47.

Radar

In 1904, a German, Christian Huelsmeyer, took out a patent in both Germany and Great Britain for “a method of detecting and recording distant metallic objects (ships, railway trains, etc.) by means of electromagnetic rays.” It would take another 30 years for interest to take root.[82] As in the United States, Navy interest in technology to detect ship movement and navigation was the impetus to radar research. The German Navy rather than the Luftwaffe began the first radar development and acquisition programs.[83]

In 1935, Admiral Raeder became Commander in Chief of the German Navy. He had a very high interest in radar and pushed for its development and wide use, initially for surface warfare. The Navy Experimental Institute worked with two firms, Lorenz and GEMA to test and develop radar. The two firms developed a cooperative rivalry, with GEMA proving to have the better technology. In March 1936, the Navy saw the need for a long-range radar set for land use in coastal and base defense. All Naval radar development, conducted in high secrecy since 1935, made it impossible for GEMA to share work with other firms except for a brief period working with Lorenz. By April 1936, the Navy did not approve of GEMA’s relationship with Lorenz because of its international businesses and prevented GEMA from sharing information with other firms, including Lorenz. Secrecy and control were so extreme GEMA could not accept orders from anyone, including the Luftwaffe or Army, requiring GEMA to work only for the Navy. Intense secrecy led to labeling the first radar as De-Te-Gerät to possibly mean Dezimeter-Telegraphie-Gerät since GEMA already produced this type of radio.[84]

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[82] Dulany Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 41.
[83] Brown, *A Radar History of World War II,* 76-78.
[84] The High Frequency War, 32; von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 33, 36, 40-41, 50, 66, 72.

The Navy ordered a radar for sea called the Seetakt or De-Te-I and the De-Te-II called Flum for *Flugmeldung* (air reporting) for land based air reporting, which was the precursor to all other German radars and led to Germany's first early warning radar. Minor changes in design gave the De-Te-II a range of 75km, longer than the Te-De-I.[85] The Navy took possession of the Te-De-II in early 1938.[86] Very little communication or technology sharing between the Navy and Luftwaffe occurred, resulting in the Navy making a decision to build an early warning radar without Luftwaffe knowledge or input.[87]

The Luftwaffe first became aware radar's existence during a July 1938 GEMA demonstration of the Navy's new De-Te-II to Hitler, Göring, Raeder, and Halder. The Navy did not tell nor invite Göring's Chief of the *Luftnachrichtentruppe*, Germany's Air Signal Corps, Colonel Wolfgang Martini, to the demonstration, tremendously upsetting Göring. The Navy told Göring this was a Navy program and to invent his own. Actual obstruction on the Navy's part, not only silence or withholding of data, marked the interservice rivalry. The Navy attempted to prevent the Luftwaffe from acquiring equipment from GEMA because the Navy considered it their source for technology and production.[88] Despite these early obstructions, some cooperation between the Navy and Luftwaffe in early 1940 set standards for supply and radar maintenance.[89]

The Luftwaffe immediately ordered the Te-De-IIs and soon after receiving them, the Luftwaffe Signal Troops (*Nachrichtentruppe*) labeled the new radar "Freya." Shortly after the July radar demonstrations, FLAK

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[85] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 50, 54, 56.; Werner Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, Schiffer Military/Aviation History (Atglen, PA: Schiffer Pub., 1998), 3.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 194, 304.
[86] Buderi, *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution*, Sloan Technology Series, 202.
[87] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 50, 75-76.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 78.
[88] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 78.; von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 75-76.
[89] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 96.

units began testing radar sets in Fall 1938 to include the GEMA air warning (A-1) Lorenz FLAK (A-2), and Telefunken Darmstadt (A-3). The A-2 and A-3 tracked in 3-D, and the A-1 only in range. Although the A-1 lacked height information, FLAK saw a need for the De-Te-II and how it could support gun-laying radars.[90] Germany identified the need for mobile and light radars that fit into the German concept of war. They requested radar that could be set up quickly and moved by tractors and trucks as well as on railroad trains. This led to the creation of a special base to hoist the A-2 onto a train car.[91] Germany also mounted both radar and searchlights onto railroad car.[92] However, it never developed the truly mobile radars or processes and concepts for offensive operations, as did the Americans or British.

Colonel Martini was enthusiastic and knowledgeable, but unable to sell radar's potential to higher leadership.[93] The inability to sell radar and higher leaderships' inability to understand radar's potential resulted in no radar or anti-aircraft radars in use during the Polish campaign, no radars during the French campaign, and the slow development and execution of intercept procedures.[94] Slow radar acquisition resulted in delayed integration into units and hence delayed development of radar employment methods. This in turn resulted in low numbers of equipment and delayed development of fighter control.

The nomenclature used for German radar sets, called *Funkmessgerät* (FuMG), provides information about the radar. Next came a two-year digit indicating the introduction year, then the first letter of the manufacturer, followed by a lower-case letter indicating the radar's

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[90] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 77, 88, 100.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 78.
[91] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 86-88, 100-01, 17, 52.
[92] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 268.
[93] Brown, *A Radar History of World War II: Technical and Military Imperatives,* 78.
[94] Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 3.; von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 103.

frequency.[95] A final upper-case letter indicated the kind of base and the manner in which the antenna could be traversed.

A = ground, fixed, mechanical traverse

B = ground, mobile, mechanical traverse

D = ground, rotatable base mounted on a bunker

F = ground, fixed, electric scanning by phase control

L = ship, rotatable base on the bridge

M = ship, rotatable base on a mast

O = ship, rotatable base on optical range finder

P = ship, fixed antenna

U = submarine

Z = ground, demountable base.[96]

In the fall of 1943, Germany changed the system for security reasons by using the numbers 400 to 499.[97]

Named after the Norse goddess of love and beauty, the Freya, the Luftwaffe's name for the De-Te-II, was comparable to the American SCR-270. It was the most famous and extensively produced German early warning radar.[98] The first operational Freya provided a long-range panoramic picture, out to 150km with no height data, while the Würzburg, a gun laying radar, provided detailed height azimuth information.[99] Three magnified A-Scopes provided track information, it was IFF capable, easily jammed and weighed about five tons,

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[95] Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 5.; von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 104.

[96] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 104.

[97] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 104.

[98] "German Radar," *Radar*, no. 2 (May 1944): 5.; Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 5.

[99] "German Radar," 5.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 282.; von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 51.; J.R. Birkhold, "Enemy Radar," (Maxwell AFB, Alabama: Air Force Histrorical Research Agency, January 1944).; George Raynor Thompson, *The Signal Corps: The Test (December 1941 to July 1943)* (Washington,: Office of the Chief of Military History Dept. of the Army, 1957), 43.; Kammhuber, "USAF Historical Studies: No. 179, Problems in the Conduct of a Day and Night Defensive Air War," 55.

transportable by railcar or 28 horses.[100] It could operate alone, but most often operated with the Würzburg, tracking the target to about 40 km before handing the track off to the Würzburgs.[101]

Field units received the first Freya by the end of 1938 in time for use in Czechoslovakia where the units gained knowledge about how terrain affected radar.[102] By 1 September 1939, only eight Freyas existed, all located in the North Sea and under Navy control.[103] On 25 October 1939, the Luftwaffe ordered 30 Freyas for AAA units.[104] On 18 December 1939, Germany made its first air kill with radar from one of these Freya radars when Royal Air Force Wellington bombers were tracked by a Freya radar on Heligoland and Wangerooge and intercepted by fighters.[105] The Germans claimed 34 British bombers, while the British records show a loss of only 12.[106] Regardless of the discrepancy, the Germans viewed this as a great victory that validated radar's potential.

Despite this success, the Freya was still inaccurate and had no height capability. The introduction of the AN circuit improved the Freya's azimuth capability, but it still lacked a height capability until the Freya-Fahrstuhl's introduction in mid-1940.[107] The Freya-Fahrstuhl set had an adjustable antenna (by 20 meters) and very good height finding capability, fixing the earlier height data deficiency.[108] The Freya-Fahrstuhl improved range out to 65km at 200 meters and 185 km at 8000 meters.[109] With special modifications, such as the AN circuitry and

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100 "German Radar," 5.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 268.
101 "German Radar," 5.
102 Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 3.
103 Grabmann, *USAF Historical Studies: No. 164 German Air Force Air Defense Operations 1933-1945 Vol 1,* 202.; Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 3.
104 Grabmann, *USAF Historical Studies: No. 164 German Air Force Air Defense Operations 1933-1945 Vol 1,* 305.
105 Buderi, *The Invention That Changed the World,*202.
106 Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 4.
107 Aders, *History of the German Night Fighter Force, 1917-1945*, 22.
108 Brown, *A Radar History of World War II: Technical and Military Imperatives*, 280.
109 Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 36.

the FuG 25 A Erstling IFF, the Freya could be used for fighter control.[110] This method, but with two Würzburg-Riese and the Seeburg Table, was still used in 1944. It allowed the control of one fighter against two enemy aircraft.[111]

Telefunken designed the Würzburg in 1937 and demonstrated it to the Luftwaffe in 1938. Designated as the FuMG (FLAK) 39T Würzburg A, it had an initial range of 7.5 miles, high directional accuracy, and a common antenna.[112] By 1939, it was able to provide a 3-dimensional picture, providing range, height and bearing information, could see and continuously track aircraft out to 25 miles, and used a data transfer system called Malsi to link several batteries to concentrate AAA fire.[113] It had a 9-foot dish elevated by hand crank, was mobile, weighed 2.2 tons, and simply and excellently engineered.[114] Placing the Würzburg radar on railway cars made it and AAA mobile.[115] Subsequent improvements led to the FuMG (FLAK) 39 T C and D, and re-designation as FuMG 62A-D in the fall of 1939.[116]

The Würzburg required six personnel to operate the six scopes: one to pass altitude via telephone to command and control or searchlights, one to get bearing and pass it by radio, one to get range from the CRT, one to get height, and a controller to manually set the elevation angle

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110 Kammhuber, "USAF Historical Studies: No. 179, Problems in the Conduct of a Day and Night Defensive Air War," 174.
111 Oberkommando der Luftwaffe Lw.-Fuehrengsstab Ausb. Abt. Nr. 1410/44 geh., "Reichluft-Verteidigung," (Freiberg, Germany: Bundesarciv/Militararchiv RL2II/366, September 1944), Heft 2, 15.
112 Brown, *A Radar History of World War II*, 80.
113 "Countermeasures War," *Radar*, no. 6 (15 November 1944): 17.; Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 6.; AAFSAT Course Lecture, "Enemy Radar," January 1944, Call # 248-25.24, in the USAF Collection, AFHRA, Maxwell AFB AL.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 282.
114 "German Radar," 6.; "Countermeasures War," 17.; Kroge, *GEMA: Birthplace of German Radar and Sonar*, 116.
115 Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 15.
116 Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 6.; Kroge, *GEMA : Birthplace of German Radar and Sonar*, 115.; von Renz, "USAF Historical Studies: No. 194 the Development of German Antiaircraft Weapons and Equipment of All Types up to 1945," ed. USAF Historical Division Research Studies Institute (Air University, Maxwell AFB, Alabama, 1958), 305.

and bearing of the radar. When the Übertragungsgerät-37 (U-37), a data transfer device, did not work, a sixth man passed the range via radio.[117] The entire operation was very labor intensive.

Air Interception Radar

Unlike the British, Germany had not identified the need for a radar centric air interception radar before the war. Instead, it used an infrared detector called the Spanner I, but discontinued its use in 1941 because it did not work well: it lacked the ability to see through the weather. For long-range visual acquisition, the Germans utilized a large telescope called the Spanner II.[118] This reflected the overarching lack of thought regarding defenses, but really reflected the lack of foresight regarding technology. War and the application of radar from the ground sparked the development of German air interception radar.

Identification Friend or Foe

Civilian firms began research into IFF, called Kennungsgerät (recognition apparatus), in 1937, settling on the same interrogation response process as the American and British systems, giving it a range of 250 km.[119] By November 1938, the German military became aware of aircraft recognition problems and quickly integrated the IFF concept developed by civilians. Germany never implemented a common IFF system for all forces as suggested by AAA in 1939.[120] The first IFF produced, "Zwilling," was not a good IFF set, but served as the foundation for IFF usage within the German military.[121] "Stichling" was the Würzburg radar IFF and could identify in direction but not in range. A need quickly arose to have IFF respond to multiple frequencies due to

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[117] "German Radar," 6.; Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 8.; "Countermeasures War," 17.
[118] "German Radar," 9.; Kammhuber, "USAF Historical Studies: No. 179, Problems in the Conduct of a Day and Night Defensive Air War," 51.; Aders, *History of the German Night Fighter Force, 1917-1945*, 39.
[119] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 78, 100.
[120] von Renz, "USAF Historical Studies: No. 194 the Development of German Antiaircraft Weapons and Equipment of All Types up to 1945," 324.
[121] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 130.

the various radars in existence operating on different frequencies. This required a versatile IFF set. General Martini wanted the Freya and Würzburg IFFs combined, but he garnered little support and it took until 1940 to receive a better IFF set.

Conclusion

During the interwar period, Germany clearly understood the need for command and control of defensive operations. It developed the organizations charged with air defense to include the division of regions, an aircraft reporting service, and the processes to warn of incoming enemy aircraft. Germany, however, still relied on WWI sound locators until near the start of the war and relied heavily on AAA.[122] They did not purposely seek new technologies to solve the early warning problem or refine the system of using fighters for air defense. No formal organization existed to plan, develop, and integrate technologies. Even once radars became available at the last moment, no attempt emerged to create and practice aircraft control as it did in the UK. Germany failed to think comprehensively of the requirements for an effective command and control system despite having a need for air defense.

There are several reasons for this lack of vision. First, the rapid expansion of the Luftwaffe focused on visible aspects of airpower such as aircraft and AAA. Second, German pilots viewed technological enhancements such as radio and AI as unnecessary, and against the view of aerial warfare as a dual between modern knights. Third, the Nazi culture of empire building hampered the proliferation of ideas. Finally, the simple reason that no one in a position of authority or influence asked how command and control could be done better as occurred in the UK.

[122] Schliephake, *The Birth of the Luftwaffe*, 38; Edward B. Westermann, *Flak: German anti-aircraft defenses, 1914-1945* (Lawrence: University Press of Kansas, 2001).

Conversely, Germany had a very strong need to develop an air-to-ground command and control system and it received support from not only Luftwaffe officers, but also Army officers. Air-to-ground command and control was something visible, tangible, and more easily envisioned. German offensive doctrine both in terms of airpower and Germany's quest for the battle of annihilation made defensive measures and thoughts mute if wars were to be short. The same offensive thought however, led the Luftwaffe to be the first air service to develop a rudimentary air-to-ground command and control system other nations soon copied.

Section Summary

Organization

Organizationally, the three nation's air services were different, and understandably so. The RAF was independent; the Air Corps was a branch of the Army through WWII; and in Germany, the air arm was under the Army and heavily circumscribed by the articles of the Versailles Treaty until gaining independence in 1935.

All three nations developed strategic bombing doctrines, although the UK and US developed the means to execute it while Germany did not due to resources, instead focusing on tactical or "operational" bombing as the best means of applying air power. Nonetheless, the Luftwaffe clearly expressed an offensive minded doctrine. The UK and US neglected air-to-ground doctrine until the start of the war. Germany did not, instead developing a rudimentary but workable system for air-to-ground operations before 1 September 1939. It would change and grow exponentially after the invasion of Poland.

All three nations developed command and control processes because of defensive requirements. The UK focused on defensive command and control despite very strong RAF inclinations to focus on offensive operations. Politicians kept defense on the forefront and in the end forced the issue. The UK developed its command and control system systematically and over a long time.

In the US, the Air Corps used defense as a means to find relevancy, but did not pursue command and control systematically until 1939. The Air Corps allowed the debate between bombardment and pursuit to hamper command and control concepts, possibly because a robust command and control system would highlight strategic bombing's deficiencies. It was a few vocal airmen, but mainly the Coastal Artillery Corps pushing command and control development, to include the technology required for early warning.

German command and control also developed from defensive needs and the constraints of the Versailles Treaty. With no offensive weapons (aircraft) allowed, Germany had to rely on command and control to provide information in order to utilize its AAA, for which it had an abundance to compensate for the lack of fighters, and therefore heavily relied upon. Offensive thought, and almost 20 years of AAA as the main component of the defensive command and control structure, hampered the integration of fighters into the system. It does not however explain the lack to improve the early warning system with technology.

Processes

All three nations left WWI with command and control processes in place for air defense and all were essentially the same. Air-to-ground processes at the end of WWI were rudimentary and incomplete. All three nations continued to build on their command and control processes throughout the interwar period, but the British developed the most useful for two reasons: radar and the systematic development of a process to move data efficiently from multiple inputs, to a central area, and then back out for execution. Fighter Command made higher-level strategic decisions at headquarters in Bentley Priory, but left the operational execution and decision making to its Groups.

The US slowly improved their processes but did not have them in place before the war. The US would have to build on the British model. Germany had a command and control process in place, but did not have the early warning tools, or the fighter aircraft to make it a truly effective system. For air-to-ground command and control, Germany had the most robust system followed by the US and then Britain, who found itself completely unprepared.

Technology

By the start of WWII, all three nations had radios for use in air-to-air and air-to-ground operations, as well as radar, but only the UK entered the war with operational AI and IFF. The UK did so for two reasons: organization structure/behavior and public fear. Experience of the London bombings during WWI fed the public and government's fear of future attacks. This in turn led to active government participation in defensive planning efforts. Second, organizationally, the government played very active roles through various committees, which provided viewpoints outside military ones. Third, empowered civilians in the Air Ministry were open to scientific solutions. Once the process began, the scientists and military personnel were able to parlay advances into other parts of the command and control system and smoothly integrate them into the organization and with existing processes or create new ones. The British purposefully guided technological advancement.

The US and especially the Air Corps did not focus technological efforts on early warning. It was the Signal Corps, in attempting to solve a problem brought to them by the Coastal Artillery Corps, which solved the early warning problem. They did so however with very little funding or support, instead relying on Coastal Artillery Corps need and in house genius. The advances however did not immediately spawn additional ideas, as in the UK, on how to use the technology in other areas of the command and control system.

The UK detected its first aircraft in July 1935 and had a complete command and control system functioning 24 hours a day by April 1939, a period of less than four years. In contrast, the US Signal Corps detected its first aircraft in December 1936 and by December 1941, five years later, a command and control system did not exist. If it had existed, the young men operating the SCR-270 in Hawaii on December 7, 1941 would have been able to use it after seeing the entire Japanese air fleet on its scopes.

In Germany, despite the Navy having the technology since 1935, did not reveal its existence to the Luftwaffe until July 1938, thus the Luftwaffe had only a few radars before the start of the war. The Luftwaffe did not have time to fully integrate them into the existing command and control structure. As with the U.S. Air Corps, the Luftwaffe did not actively seek technology to improve early warning over existing listening devices.

Overall, the interwar period highlights the key point that the creation of a command and control system requires purposeful development. It further demands an ability to either be doctrinally open or have an outside agency force change and development because they are able to see the operational environment from a different perspective. Technology and process require careful cultivation and work best when collaborative between and within military branches and civilian industry. Stovepipes and branch or service rivalries are hindrances.

Chapter 5

World War II

At the start of WWII each of the three nations had various strengths and weaknesses. The UK had a very strong air-to-air command and control system and a non-existent air-to-ground command and control system. The US had two additional years to prepare, but still did not have a well functioning system as experience at Pearl Harbor and North Africa showed. It did however have a strong foundation from which it rapidly grew its command and control capabilities into an effective system for both air-to-air and air-to-ground. Germany entered the war with a very strong air-to-ground system and despite a strong air defense system, an incomplete air-to-air command and control system.

Each nation's command and control systems, air-to-air and air-to-ground, improved as a result of war. War forced each nation to improve its systems. The experience of each nation indicates that while command and control does not guarantee victory, some command and control is extremely important to prevent failure. Command and control systems do not need to be perfect, they just have to be effective enough. Both the UKs and Germany's air-to-air command and control systems were effective enough to make operations prohibitive, forcing the enemy to continuously adjust. By the end of the war each nation had highly developed command and control systems for both air-to-air and air-to-ground in terms of organization, processes, and technology.

The United Kingdom

The United Kingdom began World War II rather well prepared regarding the command and control of air forces. Despite not having an air-to-ground command and control system in place, the UK adapted the command and control concepts, especially processes and technology established in Fighter Command for air defense, to other operations.

Army and RAF perceptions of who controlled airpower proved to be the largest obstacle to creating an air-to-ground command and control system. Once Churchill settled the issue for the services, a system took root and flourished. The command and control system also had enough flexibility to defend against a new and more advanced threat—the flying bomb.

Organization and Processes

Battle of Britain

After the United Kingdom's declaration of war on 3 September 1939, Fighter Command continued to prepare for the expected onslaught. Until then, Fighter Command's command and control system helped protect British shipping. Minor skirmishes between the RAF and Luftwaffe occurred until May 1940.[1] Fighters supporting the Army in France operated from the continent owing to the lack of fighter range. In supporting the withdrawal from Dunkirk, fighters operated from a single base in Kent, again due to fighter range limitations. The halting of German armored units at Dunkirk and the command and control system, however, assisted the fighters in ably covering the withdrawal from the continent.[2]

For Britain, the Battle of Britain officially started on 10 July 1940 and ended on 31 October 1940. Most German sources use a beginning date of 13 August 1940, with the battle not ending until May 1941.[3] The battle is sufficiently well known to make a full recounting unnecessary, but the command and control system functioned brilliantly, helping Fighter Command achieve a 1.8 to 1 kill ratio (1023 to 1887).[4] The command and control system was a force multiplier allowing Fighter Command to overcome a larger and in some ways stronger enemy.

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[1] Collier, *The Defence of the United Kingdom*, 77-95.
[2] Collier, *The Defence of the United Kingdom,* 111-117.
[3] Wood and Dempster. *The Narrow Margin,* 13, 21.
[4] Stephen Bungay, *A History of the Battle of Britain* (London: Aurum Press Ltd., 2009), 368.

German intelligence knew of British radar, but believed it primitive based on the CH's 12 m wavelength versus the much smaller wavelength used by Germany.[5] The Germans quickly learned from intercepting British radio communications from ground controllers providing British fighters with detailed enemy positions and vectors, yet failed to appreciate what that meant. The Germans believed the British employed a rigid territorial division easily swamped with massed attacks. This was not the case; the British skillfully adjusted their deployments and were not overwhelmed. Ironically, the British swamped the German command and control system later in the war with compressed bomber streams and Window, or chaff.[6] The British also seamlessly integrated their Y-Service to assist with intercepts.[7]

After the Battle of Britain

With the battle over, the threat of invasion receded although attacks did continue during the day and at night. Effective defense at night was only possible with a command and control system, requiring special skills and much more precise equipment. The equipment developed specifically for night fighting was the Ground Controlled Intercept (GCI) radar and Air Interception (AI) radar onboard fighter aircraft. These two pieces of equipment integrated into the existing command and control system, following the same fighter control processes already in place. The major difference between the two was that control occurred at the GCI station rather than with the sector controllers. The sector controller handed fighters to various GCI controllers as necessary to defend against incoming enemy aircraft. The GCI controller's job entailed getting the fighter as close as possible to the enemy aircraft, thereby enabling the fighter's AI to detect the enemy.

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[5] E. R. Hooton, *Eagle in Flames: The Fall of the Luftwaffe* (London: Arms & Armour. 1997), 171.
[6] Great Britain, *The Rise and Fall of the German Air Force, 1933-1945* (London: Arms and Armour Press, 1983), 80-81.
[7] Hooton, *Eagle in Flames*, 13.

Once that occurred, the fighter pilot completed the intercept. If necessary, one GCI station could pass the fighter on to another GCI station. GCI stations were the first to use VHF for fighter control and to maintain a redundant means of communicating with Fighter Area Control in case of telephone failure. One officer and eight enlisted troops operated a GCI station.[8]

By December 1939, experience confirmed the superiority of the fighter over the bomber, especially one aided by a modern command and control system. Daylight attacks on Germany proved prohibitive, forcing the RAF to switch to night bombing.[9] The British watched the Americans learn the same lessons in 1943 at Regensburg and Schweinfurt, where it became "clear that unescorted daylight attacks could not go on."[10]

The command and control system played an important role in British and American raids and in strategic attacks into Germany and German held territory before and after the invasion. The next chapter provides the details of these raids and attacks. Before the British and Americans combined operations, however, the British first developed a comprehensive air-to-ground command and control system to complement that existing for air defense.

Air-Ground Cooperation

Interservice rivalry characterized the period from September 1939 through December 1941 due to the Army and Navy's desire for total control of air assets to support their operations and the RAF's insistence that airpower had a much broader role. Disagreement centered on who controlled the airpower conducting ground and maritime operations, rather than on organizational structure and processes. Operational control of air forces was the solution consistently proposed by the British

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[8] "The Tactical Employment of Night Fighters," Call # 248.282-3, pp. 4-6, in the USAF Collection, AFHRA, Maxwell AFB AL.

[9] Joubert de la Ferté, *The Third Service,* 128.; Jones, *The Beginnings of Strategic Air Power*, 169-170.

[10] John Slessor, *The Central Blue*, 431.

Army.[11] Conversely, the RAF held to its beliefs regarding airpower's strategic role and the need for centralized control. The two services' diametrically opposed concepts of control stunted the development of a solution.

Before 1939, both RAF and Army doctrine specified an air component would accompany the Army under the control of GHQ while other aircraft from the RAF also provided support. When the British Expeditionary Force (BEF) deployed to France, the Advanced Air Striking Force, RAF (AASF), an "outpost of Bomber Command" under RAF operational control, and the Air Component of the Field Force, provided the BEF with direct support. The Commander-in-Chief, BEF, General Lord Gort had operational control of the Air Component with Air Vice-Marshal C.H. Blount the Air Officer Commanding (AOC) as his chief air advisor. Air Vice-Marshal P.H.L. Playfair had operational command of the AASF. Four fighter squadrons, four tactical reconnaissance (Army Co-operation Squadrons) and four strategic reconnaissance squadrons comprised the Air Component. Gort did not deem a joint headquarters to control airpower necessary.[12] The RAF however felt co-located headquarters improved operations. It remained a concept the RAF pushed consistently throughout the war and proved critical to good interservice relations and success on the battlefield.

An extremely convoluted process for air support requests contributed to continuing disputes between the Army and RAF over ground support. Air requests for external support began with the Army in France and went to the War Office, then to the Air Staff, and finally to the AASF in France. The creation of the British Air Forces in France (BAFF) by combining the AASF and the Air Component under a single air

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[11] David Ian Hall, *Strategy for Victory: The Development of British Tactical Air Power, 1919-1943* (Westport, Conn: Praeger Security International, 2008), 42.; I. S. O. Playfair, *The Mediterranean and the Middle East. Volume II: The Germans come to the help of their Ally (1941)* (London: H.M.S.O., 1956), 286.; W. A. Jacobs, "Air Support for the British Army," *Military Affairs,* (December, 1982): 176.
[12] Hall, *Strategy for Victory*, 41-42.; Jacobs, "Air Support for the British Army," 174.

commander attempted to solve this issue by consolidating air power and making all aircraft, including bombers, available to support ground operations.[13]

The consolidation of airpower, however, was not enough to create an adequate air support system in France. Insufficient contact still existed between the Army and RAF, headquarters were not co-located, and the system lacked an "extensive and reliable communications network."[14] Failure resulted in accusations from both the RAF and Army. The Army response to the failure in France, written by General Gort, emphasized the need for better long distance secure communications, anti-aircraft weapons, anti-tank defenses, and more aircraft under direct Army control. Naturally, the RAF assessment disagreed with the Army verdict regarding the support system. The RAF believed the basic concepts of moving information back and forth from ground and air units to a headquarters for a decision was sound and attributed the problem to not having air representation at Army headquarters or a joint air/army command.[15]

During autumn 1940, the RAF took steps to improve cooperation with the Army, especially with a German invasion looming. First, in support of home defense requirements, the RAF established a Combined Central Operations Room at GHQ Home Forces to coordinate air requests in the event of an invasion. Unlike in France, the Army could request air support directly to Bomber Command. Additionally, each Army command in Great Britain also had a Combined Operations Room linked via telephone and wireless to No 1 and No 2 Groups in Bomber Command. All aircraft, however, remained under RAF operational control. Second, the Air Staff proposed an "RAF Army Co-operation Command to study

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[13] Hall, *Strategy for Victory, 1919-1943*, 49.; Jacobs, "Air Support for the British Army," 174.
[14] Ian Gooderson, *Air Power at the Battlefront: Allied Close Air Support in Europe, 1943-45* (London: F. Cass, 1998), 22-24.
[15] Hall, *Strategy for Victory*, 53.

and develop all forms of air support for the army." This command came into being on 1 December 1940, combining all aspects of air-to-ground cooperation to include training and technical integration.[16]

Concurrently, joint Army/RAF experiments occurred in North Ireland in September and October 1940 under Group Captain A.H. Wann and Colonel J.D. Woodall, "to determine 'the most appropriate methods both tactical and technical for the development of air bombardment in close support of land forces.'"[17] The experiments resulted in the creation of Close Support Bomber Controls (later changed to Army Air Support Control), and a communications network connecting air and ground commanders with army front units, RAF aerodromes, and advance landing grounds. Corps, Divisions, and Brigade HQs received a Royal Corps of Signal operator and Army Air Liaison Officers (ALO) to form a "tentacle," modeled after the German technique. They utilized light vehicles and communicated with the control centers, passing information and requesting air power. Aerodromes monitoring the network received information to launch after a brief from the ALO regarding targets and the most current bomb line. RAF reconnaissance also used the network to provide information to air and ground units. With its creation in December 1940, Army Co-operation Command adopted this system.[18]

Simultaneously, limited British resources in the Middle East in 1940 forced the services to work together and required the centralization of air power.[19] The Army placed Air Intelligence Liaisons in the Army Co-operation Squadrons and Fighter Squadrons to brief and debrief pilots on the current ground situation. Squadrons had direct links to the Corps or Divisional headquarters they were supporting. Headquarters attempted to be within 10 miles of each other.[20]

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[16] Hall, *Strategy for Victory*, 63, 67, 90-91, 93.
[17] Hall, *Strategy for Victory*, 91.; Gooderson, *Air Power at the Battlefront*, 24.
[18] Hall, *Strategy for Victory*, 92-93.; Gooderson, *Air Power at the Battlefront*, 24-25.
[19] Hall, *Strategy for Victory, 1919-1943,* 68-70.
[20] Hall, *Strategy for Victory*, 71.

After success against the Italians in 1940 and 1941, the first large scale British encounter with the Germans led to defeat at the Battle of Sollum (Battleaxe) in Egypt in June 1941. The battle highlighted several deficiencies. “British aircraft and tactics were unsuited for air support, C3I systems could not keep pace with the battle or guide aircraft to their targets, nor could British ground forces stand against the Afrika Korps in mobile battle.” The RAF, as it did after operations in France, blamed the breakdown in communication as the primary inability to conduct air-to-ground operations.[21] After the battle, the Army Commander, General Auchinleck, cabled Churchill regarding Auchinleck’s need for air forces and the need to control them.[22] Churchill replied clearly,

> I feel that for all major operational purposes your plans must govern the employment of the whole air force throughout the Middle East, bearing in mind, of course, that the Air Force has its own dominant strategic role to play and must not be frittered away in providing small umbrellas for the army, as it seems to have been in the Sollum battle (Battleaxe’). You speak of aircraft supporting the navy and aircraft supporting the army and aircraft employed in independent strategic tasks. The question is what are the proportions? These will have to be arranged from time to time by the Commanders-in-Chief in consultation. But nothing in these arrangements should mar the integrity of the air force contribution to any major scheme you have in hand. One cannot help feeling that in the Sollum fight our air superiority was wasted….[23]

With this broad guidance, the Army, and RAF conducted exercises to improve integration.[24]

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[21] Brad William Gladman, *Intelligence and Anglo-American air support in World War Two the Western Desert and Tunisia, 1940-43* (Basingstoke [England]: Palgrave Macmillan, 2009), 60.
[22] Playfair, *The Mediterranean and the Middle East. Volume II*, 287.
[23] Playfair, *The Mediterranean and the Middle East. Volume II,* 287.
[24] Playfair, *The Mediterranean and the Middle East. Volume II,* 294-295.

Despite the progress, friction continued between the RAF and the Army. Churchill thought the RAF was not "all in," and threatened creating a separate army air branch if cooperation/support was not forthcoming. The Army continued to insist on full time air defense or air "umbrellas," which the RAF thought costly and wasteful. The RAF suggested using AAA, but the Army wanted airpower and operational control of those aircraft. Finally, on 5 September 1941, Churchill once again admonished his Army Commander, and issued a Directive to the Commander–in-Chief Middle East, stating,

> Nevermore must the ground troops expect as a matter of course, to be protected against the air by aircraft. If this can be done it must only be as a happy makeweight and a piece of good lick. Above all, the idea of keeping standing patrols of aircraft over moving columns should be abandoned. It is unsound to distribute aircraft in this way, and no air superiority will stand any large application of such a mischievous practice. Upon the military Command-in-Chief in the Middle East announcing that a battle is in prospect, the Air Officer Commanding-in-Chief will give him all possible aid irrespective of other targets, however attractive. Victory in battle makes amends for all, and creates new favorable situations of a decisive character. The Army Commander-in-Chief will specify to the Air Officer Commanding-in-Chief the targets and tasks which he requires to be performed, both in the predatory attack on the rearward installations of the enemy and for air action during the progress of the battle.[25]

The directive resulted in a joint agreement and the release of Army Training Regulation No 6. The new directive followed the principle of first establishing air superiority, then isolating the battlefield, and finally attacking tactical targets. The Americans adopted this priority when they

[25] Playfair, *The Mediterranean and the Middle East. Volume II,* 288.

released FM 100-20, *Command and Employment of Airpower*, after its first combat experiences in North Africa. Additionally, Churchill's directive led to the creation of an Army Co-operation Force (Recce) under Army control with fighters/bombers remaining under RAF control, the colocation of Army and RAF headquarters, and the use of the AASC to attack emerging targets.[26] It also led to the creation of "Middle East Training Pamphlet (Army and Royal Air Force) No. 3-Direct Air Support" and an Air Support Control Headquarters. The document defined direct support as having "an immediate effect on the action of our ground forces in battle." This could be pre-arranged or impromptu. Otherwise, it was indirect air support outside the tactical area. Direct air support depended to a degree on air superiority. It also defined how to identify troops, target selection, communications, and aircraft readiness states.[27]

Air Support Control (ASC) Headquarters directed airpower with one ASC for each corps and armored division headquarters comprised of a joint staff, linked by two-way wireless to the brigades, known famously as tentacles. Each brigade had a RAF team called a Forward Air Support Link (FASL) with two-way wireless to control aircraft. Rear Air Support Links (RASLs) conducted two-way communications with airfield and forward landing grounds. ASC RAF personnel also had communication equipment to listen to aircraft talking to the FASLs and served as a clearinghouse.[28]

Brigades or even reconnaissance aircraft made air support requests through the FASLs to the ASC. Once evaluated and if approved, the approved request went to the RASLs and FASLs with execution

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[26] Hall, *Strategy for Victory*, 102.
[27] Playfair, *The Mediterranean and the Middle East. Volume II,* 295.; I. S. O. Playfair, *The Mediterranean and Middle East. Volume III: September 1941 to September 1942: British fortunes reach their lowest ebb* (London: H.M.S.O., 1960), 13-14.
[28] Playfair, *The Mediterranean and the Middle East. Volume II*, 295.

details, much as with the system developed in the UK the previous autumn. Aircraft reported to the FASLs for tactical control to the target.[29]

Before the next major operation, Crusader in November-December 1941, the system changed in order to centralize airpower. The ASC HQ, under the Air Officer Commanding (AOC), Desert Air Force, retained control of all air assets. The 8th Army Commander concurred with this new process. This meant the ASCs passed information, but the AOC made the decisions.[30] Other improvements included better communication methods and more airpower. Tedder made every squadron available to Coningham for Crusader. Coningham also co-located his headquarters with that of the 8th Army Commander, living and moving with him as they executed the joint plan.[31]

The UK and desert systems fused in 1942 after a UK unit came to the desert bringing improvements, and by summer 1942, the British had a good system in place.[32] Amazingly, however, neither the British nor the Americans incorporated the early lessons from the East African campaigns for Torch. The British Eastern Air Command (EAC) and Twelve Air Force were under Northwest African Air Forces (NAAF). Under Eastern Air Command was No 242 Group. They used their fighters defensively, had no wireless organization or trained communication personnel, and no centralized fighter control center or radars. US XII ASC under Twelve AF also had no centralized fighter control or adequate radars.[33]

Additionally, very little air coordination occurred between the two air forces due to their geographic division. On 25 January 1943, Lieutenant General Carl Spaatz, commander of NAAF placed No 242

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[29] Playfair, *The Mediterranean and the Middle East. Volume II*, 295.
[30] Playfair, *The Mediterranean and Middle East. Volume III*, 13-14.
[31] Playfair, *The Mediterranean and Middle East. Volume III*, 208.
[32] Hall, *Strategy for Victory,* 116.; Gooderson, *Air Power at the Battlefront*, 26.
[33] I.S.O. Playfair, C.J.C. Molony, F.C. Flynn, and T.P. Gleave. *The Mediterranean and Middle East, Volume IV: The Destruction of the Axis Forces in Africa* (London: H.M.S.O, 1966), 300-310.

Group and XII ASC under a single organization called Allied Air Support Command, later North Africa Tactical Air Force (NATAF); bomber requests now flowed back to EAC and Twelve Air Force.[34] When Coningham took over NATAF, he made changes based on his earlier experiences. He eliminated penny packets, centralized bomber forces, improved training, radar coverage, and communications, and made air superiority the number one requirement. Coningham created the critical command and control system needed to maximize air power's potential.[35]

While the command and control system developed in 1942 remained the basis for the air-ground control system throughout the war, small improvements continued until the end of the war. For example, the Air Support Signals Unit (ASSU) of the Royal Corps of Signals became formally responsible for and created a standardized system of tentacles to deploy at any level. It consisted of a vehicle with three crews. They did not report to their attached commands, but rather to the operations staff of the command controlling them. As expected, preplanned operations worked well while impromptu request had slower response times due to communication links, discussions, and aircraft flight times.[36]

Forward Control Posts (FCPs) or ROVER, created during the Italian campaigns to reduce the response time for air requests, provided visual fighter and reconnaissance control. It had a senior RAF controller, usually a Wing Commander, an officer from the Army Air Liaison Group, and ASSU and VHF equipment at Corps headquarters. FCPs made quicker judgments, handled urgent requests, and removed this function from the central center, thus reducing workload and the time to strike.

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[34] Playfair, Molony, Flynn, and Gleave. *The Mediterranean and Middle East, Volume IV*, 311.
[35] Playfair, Molony, Flynn, and Gleave. *The Mediterranean and Middle East, Volume IV*, 311-312.
[36] Gooderson, *Air Power at the Battlefront*, 26-27.

FCPs also received a Contact car to "enable an RAF Forward Air Controller (FAC) to communicate with aircraft at the battlefront."[37]

In response to the changing character of the war, primarily a reduced German air threat to Great Britain and allied plans for an invasion of the continent, Fighter Command ceased to exist on 17 November 1943. On 1 June 1943, 2nd Tactical Air Force came into being out of portions of Fighter Command to focus on offensive operations and based its organizational structure on the North African model. On 17 November 1943, defensive tasks fell to a new organization with an old name, Air Defence Great Britain (ADGB).[38]

Defending against the "Flying Bomb"

While an invasion ceased to be a threat, intelligence indicated a new one—the flying bomb (V-1). On June 18, 1944, five days after the first flying bomb attack on London, a flying bomb killed 58 civilians, 63 military and wounded 20, and 48 respectively, prompting a response. The allies took two actions to stop the attacks. The first involved hunting flying bomb sites in France under the code name Crossbow. Although a priority to the UK government, the military felt it a wasteful diversion of assets, with costs outweighing the benefits.[39] The second, known as Big Ben, used the command and control system to defeat the flying bombs before they could strike the UK.

The command and control system however had to perform better and faster than it already did to effectively assist in stopping the flying bombs. The British reacted by dedicating eight single engine and four twin-engine fighter squadrons against the flying bombs and redeploying Anti-Aircraft Command and Balloon Command assets.[40] The defense also relied on the existing command and control system to track the flying

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[37] Gooderson, *Air Power at the Battlefront*, 27-29.
[38] Jacobs, "Air Support for the British Army," 181.; Hall, *Strategy for Victory*, 151.; Collier, *The Defence of the United Kingdom*, 323-324.
[39] Collier, *The Defence of the United Kingdom*, 377-378.
[40] Collier, *The Defence of the United Kingdom*, 372-373.

bombs. Various CH radar stations received modifications "to facilitate the detection of such Rockets by Radar,"[41] providing the ability to continuously track a flying bomb as low as 1000-2000 feet, traveling 350 miles/hour.[42] The arrival of the American SCR-584 radar at the end of June 1944, with its highly accurate tracking capability, assisted in controlling fighter aircraft to intercept the weapons.[43]

ADGB established special procedures to deal with the flying bombs. Within No 10 Group and No 11 Group, operators assigned to particular CH radars, called "Big Ben" Operators, shouted the code word "Big Ben" when their CH radar picked up a flying bomb. This allowed tellers in the appropriate Filter Room to tell the track to the Filter Room Controller. The Filter Room plotter shouted "Big Ben" and rang a bell until acknowledged by the Filter Room Controller.[44] The controller provided airborne fighters with a running commentary on incoming bombs to facilitate an intercept.[45]

Besides controlling aircraft, the No 10 Group and No 11 Group Filter Room Controller took assorted actions to include pulling specific switches corresponding to areas/towns. This initiated various warning sirens and defensive actions such as calls to other organizations to include ADGB HQ, the Scientific Observer, adjoining Groups, and the Home Security War Office. Determining trajectory and origination point of every track identified by Big Ben operations assisted Crossbow operations.[46]

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[41] "Air Defence of Great Britain Operational Instruction No. 7A/1944. German Long Range Rockets – Code Word "Big Ben."" Call # 505.59-6, in the USAF Collection, AFHRA, Maxwell AFB AL.

[42] "HQ Ninth Air Force Intelligence Report on Flying Bombs, 24 October 1944." Call # 505.59-2, Part 1, in the USAF Collection, AFHRA, Maxwell AFB AL.

[43] Collier, *The Defence of the United Kingdom*, 378.

[44] "Air Defence of Great Britain Operational Instruction No. 7A/1944. German Long Range Rockets – Code Word "Big Ben."" Call # 505.59-6, in the USAF Collection, AFHRA, Maxwell AFB AL.

[45] Collier, *The Defence of the United Kingdom*, 374.

[46] "Air Defence of Great Britain Operational Instruction No. 7A/1944. German Long Range Rockets – Code Word "Big Ben."" Call # 505.59-6, in the USAF Collection, AFHRA, Maxwell AFB AL.

The fundamental soundness, in terms of processes and technology, of the UK's command and control system easily flexed to the new problem presented by the flying bombs. Throughout the campaign, the command and control system detected 7,588 of the 10,492 flying bombs launched by Germany. Fighters destroyed 1,847, guns destroyed 1,878, and balloons destroyed 231, for a total 3,957. The remaining 3,531 flying bombs evaded the defenses.[47]

Technology

Ground Controlled Intercept (GCI) radars, specifically developed for night fighter control and to conduct multiple intercepts, quickly served as the heart of the fighter control system. The British coined the term GCI to designate the type of radar used to control night fighters. Extremely critical to fighter control, GCI development grew out of the CHL design; the first GCI was simply a CHL with a new plan position indicator (PPI) mounted on a trailer and a Type 13 height finder working on centimeter wavelengths to provide height accuracy. The CHL radar system, designed to be more accurate than CH, provided GCI good low-level coverage. Prototype testing occurred in winter 1940-1941 with 9 of the first 10 intercepts successful. The demand was so great that the first six GCI were quickly hand made in November and December 1940, with all six delivered by the end of January 1941.[48]

Two critical design elements made GCI a wonder. First, while the first sets still used separate fixed antennas manually pointed towards the target, a single rotating antenna quickly replaced these.[49] The second was the creation of a new oscilloscope in January 1940, called the PPI. An oscilloscope allowed the measurement of signal voltage. When a

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[47] Collier, *The Defence of the United Kingdom*, 523.

[48] Brown, *A Radar History of World War II,* 117.; Bowen, *Radar Days*, 82.; Gough, *Watching the Skies,* 11, F-4; Latham and Stobbs, *Pioneers of Radar,* 27.; Wood and Dempster. *The Narrow Margin,* 145.; Latham and Stobbs, *Radar: A Wartime Miracle,* 60.

[49] Brown, *A Radar History of World War II,* 117.; Bowen, *Radar Days*, 82.; Gough, *Watching the Skies, 11.*

signal from an aircraft returned to the radar receiver, the receiver measured the signal voltage and displayed it on a cathorade tube with the target signal amplified on the oscilloscope sweep to indicate the track's location. Initially the oscilloscope began at the center of the cathorade tube and moved outward. Only later, after the introduction of a common antenna, did the standard 360-degree sweep oscilloscope come into use.[50] It rotated 360-degrees clockwise, highlighting a track's location on the oscilloscope in two dimensions, bearing and slant range. The center of the oscilloscope indicates the radar's position. By overlaying a map, the controller could determine exact geographic location, allowing a controller to control multiple aircraft.[51]

The PPI Tube provided range to 120 miles,[52] but had a 50-mile grid overlay with grids placed one inch apart to indicate 10-mile intervals while the center of the screen indicated the radar's location. The radio energy displayed on the screen as the beam rotated, producing a faint blue line that lit up brightly as a "blip" or "echo" on the PPI when the radar's energy reflected off an aircraft. The "blip" left an afterglow, assisting the operator in maintaining a history of the aircraft's position. The controller aimed the directional beam like a searchlight in order to get up to date data on the enemy's position. "In effect, the screen represents a plan view of the area surrounding the radar, hence the name 'plan-position indicator.' The advantage of the PPI is it displayed a large number of echoes simultaneously," rather than one target at a time. By this time, data from IFF equipped aircraft also instantly displayed on the same PPI scope as an additional hump on the radar "blip."[53]

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[50] Brown, *A Radar History of World War II,* 117.
[51] Gough, *Watching the Skies,* 9.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 257.; Latham and Stobbs, *Radar: A Wartime Miracle,* 60.
[52] AAFSAT Course Lecture, "Function of GCI," 31 March 1944, Call # 248.25-4, in the USAF Collection, AFHRA, Maxwell AFB AL.
[53] AAFSAT Course Lecture, "GCI-AI Team," January 1944, Call # 248.25-8, in the USAF Collection, AFHRA, Maxwell AFB AL.; AAFSAT Course Lecture, "History & Background of Night Interception,"

Next to the PPI Tube was the Height & Range Tube (H/R) rack containing a cathorade ray tube used to give accurate height to within 500 feet and range out to 120 miles for EW beyond the range of PPI.[54] A green line, the horizontal time base, provided range information. A device that divided the antenna, splitting the echo on the H/R tube, determined the altitude. A height calibration chart in front of the Height Estimator compared and filtered the length of the echoes.[55] With this information, the PPI Operator seated behind the controller read the flight and target coordinates over an intercom to the Plotter-Computer Operator located at the Integrated Board at the Craig Computer. The Plotter-Computer Operator plotted the coordinates and used the Craig Computer to determine “the speed, heading, and course of the target for the Controller.”[56]

The system of plotting information from multiple radars into a filter room and controlling from a map was too cumbersome and time-consuming. At night, the intercept had to be more accurate, and the PPI helped. The sector controller sent track information and handed the fighter over to a GCI controller. Control now began to occur directly from the PPI instead of the former method using a board map. The controller watched the PPI scope for both radar and IFF indications, and then positioned the fighter for the Air Interception (AI) radar to pick up the target.[57] This technological change caused the radar room layout and

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140, Call # 248.252-34, in the USAF Collection, AFHRA, Maxwell AFB AL.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 257.; Roger B. Colton, “Radar in the United States Army,” *Proceedings of the Institute of Radio Engineers* (November, 1945): 753.

[54] AAFSAT Course Lecture, “Function of GCI”, 31 March 1944, Call # 248.25-4, in the USAF Collection, AFHRA, Maxwell AFB AL.

[55] AAFSAT Course Lecture, "GCI-AI Team," January 1944, Call # 248.25-8, in the USAF Collection, AFHRA, Maxwell AFB AL.; AAFSAT Course Lecture, "History & Background of Night Interception," 140, Call # 248.252-34, in the USAF Collection, AFHRA, Maxwell AFB AL

[56] AAFSAT Course Lecture, "GCI-AI Team," January 1944, Call # 248.25-8, in the USAF Collection, AFHRA, Maxwell AFB AL.; AAFSAT Course Lecture, "History & Background of Night Interception," 140, Call # 248.252-34, in the USAF Collection, AFHRA, Maxwell AFB AL

[57] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 257.; Brown, *A Radar History of World War II*, 117.; Gough, *Watching the Skies,* 12.

organizational structure to change, as fewer people were now required. Despite GCI's tremendous capabilities, it initially could only deal with one intercept at a time (a skilled operator could cope with two). The solution was to add more PPI scopes and controllers to handle multiple intercepts.[58] It was so successful for the British that enemy losses with GCI increased from ½ percent in December 1940 to 7% by May 1941.[59]

By the end of 1941, Great Britain had 29 GCI with a heavy demand from the field for more. Three types were built--mobile (AMES Type 15), transportable (AMES 8), and fixed (AMES Type 7).[60] In preparation for the invasion, floating GCI built on Landing Ships, Tanks (LSTs) called Fighter Direction Tenders (FDT) were built to extend radar's range as close as possible to the shore.[61]

GCI Detection Ranges

Height of aircraft (Ft)	500	1000	5000	10,000	20,000
Range (miles)	10	30	51	67	90

Table X[62]

AI

By early 1940, the UK had developed three successive AI models; the Mark I, II, and III. All three were effective at a range of 3-4 miles or a range equivalent to the fighter's altitude, but performed poorly at low level. Continuous innovation led to the Mark IV in late 1940, considered the first really good and reliable AI set, and the Mark V in February 1941. Both the Mark IV and Mark V had the same range and altitude restrictions as previous AI sets, an accuracy of 10 degrees up and 40

58 Brown, *A Radar History of World War II*, 117.
59 Gough, *Watching the Skies,* 12.
60 Gough, *Watching the Skies,* 12.
61 Latham and Stobbs, *Radar: A Wartime Miracle*, 68.
62 Gough, *Watching the Skies,* F-4.

degrees each side off the fighter's nose, and used a cathode ray display. By October 1943, both the Mark IV and V's technology was obsolete.[63]

The fully automatic Mark VI, Mark VII, and Mark VIII appeared at the beginning of 1942. The Mark VI never went into production because the Mark VII was the first 10-centimeter wave AI. The Mark VII was a handmade version of the Mark VIII with only 125 made. The Mark VII and VIII, both 10 cm sets, had a 4-5 miles range, no altitude restrictions, .5 degree accuracy dead ahead or 5 to 10 degrees if 45 degrees off, a CRT radial time base display, and improved ground clutter reduction, but still susceptible to window jamming (same as the US SCR 520).[64]

Meanwhile, the US had created an effective research organization based on the British university pattern that involved the Radiation Labs at MIT joining with industry to pool "academic and commercial research facilities" to create advanced electronics. As a result, when the Mark IX, tested in December 1942, proved susceptible to Window, as had previous AI models, the British looked to the promising American SCR-720, also a 10 cm AI set which tested successfully that same month against Window. It had a maximum 8-mile range and 5-degree accuracy, or 2-3 degrees at 5 miles. With minor modifications, the SCR-720 became the Mark X and the standard allied radar set for the remainder of the war.[65]

Conclusion

A strong foundation in terms of organization, processes, and technology benefited the United Kingdom. While it failed to develop a command and control system for air-to-ground operations, the UK was

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[63] Bowen, *Radar Days,* 119, 129.; Latham and Stobbs, *Pioneers of Radar*, 4.; "The Tactical Employment of Night Fighters," Call # 248.282-3, pp. 4-6, in the USAF Collection, AFHRA, Maxwell AFB AL.; White, *The History of the Air Intercept (AI) radar and the British Night-Fighter 1935-1959,* 31-35, 60-63, 96.

[64] "The Nightfighters," 45.; White, *The History of the Air Intercept (AI) radar and the British Night-Fighter 1935-1959*, 99-105, 144-147, 158, 160.; Bowen, *Radar Days*, 131.; "Notes on Night Flying," Call # 512.511A, in the USAF Collection, AFHRA, Maxwell AFB AL.; "The Tactical Employment of Night Fighters," Call # 248.282-3, pp. 4-6, in the USAF Collection, AFHRA, Maxwell AFB AL.

[65] White, *The History of the Air Intercept (AI) radar and the British Night-Fighter 1935-1959*, 145, 168-170, 174.; "The Tactical Employment of Night Fighters," Call # 248.282-3, pp. 7a, in the USAF Collection, AFHRA, Maxwell AFB AL.; Bowen, *Radar days*, 131.

thoroughly prepared for air defense. This formed the foundation from which to adjust and build. The concepts, both organizational and process-related, and the technology developed for air defense were readily adapted into developing a command and control system for air-to-ground operations. However, it still took almost three years from September 1939 until the fall of 1942 before a functioning and efficient air-to-ground command and control system was in place.

Politicians once again played the critical role in moving forward with a solution, this time by settling service differences. The RAF firmly believed in the concept of centralized control and decentralized execution as evidenced by the success of the Battle of Britain. It also firmly held to the concept that airmen best understood the importance of airpower in terms of the range of its uses—airpower had a larger role in national defense besides being limited to being an extension of the Army as flying artillery. The Battle of Britain and events on the battlefields of North Africa validated the concept of centralized control and decentralized execution.

Technologically, the UK was well prepared. Both air defense and air-to-ground operations required radar and radios. Radar, especially the development of smaller and mobile radars, helped air-to-ground operations in terms of providing a defensive capability that did not require constant airborne patrols (an impossibility due to lack of resources). Early warning provided time to launch aircraft or move them from one area to another to meet the enemy. Second, radar aided offensive operations by providing an "air picture" of enemy activity and providing precision radar control during bad weather. Third, radar technology had advanced far enough for scientists to be able to make adjustments to handle the new flying bomb threat. Finally, despite the UK's early technological lead, especially regarding the magnetron and centimeter waves, collaboration with the US meant constant improvement on each other's technology and access to a massive production capability. Germany simply could not match the pooling of scientific research between the US and UK.

Comprehensive preparation during the final four to five years before the start of World War II and the ability to combine and integrate the parts required for an effective command and control system paid handsome dividends for the UK. Without the comprehensive command and control systems it developed, it may not have won the Battle of Britain or the War.

Chapter 6

The United States

Introduction

The United States entered World War II with the capability to command and control air forces. Two years of prewar preparation provided the United States a large number of trained air-to-air (air defense) and air-to-ground command and control personnel, refined doctrine, and the organizational structures required to command and control. Processes were also refined through training, maneuvers, collaboration with the British, and critical assessments. Finally, units began receiving radars in large numbers, AI technology arrived from the UK, and IFF began to proliferate to allied forces. The US, however, for a short time continued to rely on British ideas, concepts, technology, and experience before it displayed command and control effectiveness on the battlefield. US forces did not initially perform well, as the North African campaign demonstrated.

Over time however, the US's command and control capability grew into a very effective and efficient system. As with the British, the largest obstacle to an effective air-to-ground command and control system was the question of who controlled airpower. Battlefield experience and British influence quickly settled the debate. The US ably adapted its organization, processes, and technology for both defensive and offensive operations. The US proved flexible in using equipment designed for one purpose and shifting it to another to improve capability. It also successfully collaborated with the British, civilian research facilitates, and industry. The system in place at the end of the war serves as the model for today's tactical and operational command and control system.

Post Pearl Harbor

The shock of Pearl Harbor led to allocating almost all radar sets to air defense, including those slated for deployment overseas and for training. The Army quickly realized the problem at Pearl Harbor had been the air defense system as a whole, not the SCR-270 radar set itself.[1] In fact, the radar at Opana station on the north side of Hawaii picked up the attacking air fleet at 137 miles (about 45 minutes before the attack). The radar functioned well. Before the attack, the radar on the island normally operated only 3 hours a day and with a minimum staff of only 18 men. After 7 December 1941, it operated 24 hours a day and with a crew of 40 men. Additionally, no IFF existed to help the radar operators or the Information Center at Fort Shafter distinguish friend from foe.[2]

Radar sites on the west and east coast rose to a total of 41 and 31 respectively by July 1942. By April 1943, 95 sites existed in the United States, 65 of them on the Pacific Coast.[3] The mobility and flexibility provided by the SCR-270 proved advantageous.[4] Rapid increases in the amount of equipment in service was matched by personnel expansion. "Only 169 officers and enlisted men were on the rolls" at the Aircraft Warning Department, Signal Corps School, Fort Monmouth at the time of Pearl Harbor.[5] The Signal Corps immediately began ramping up its schoolhouse to meet the growing demand for radar operators and specialists.

Even after Pearl Harbor, the Army saw the problem of continental defense as largely a matter of defending against minor attacks from a carrier strike force.[6] By mid-1942 the coastline of the United States was dotted with over 250 radars; 2 SCR-271s, 70 SCR-270s, and 194 SCR-

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[1] George Raynor Thompson, *The Signal Corps: The Test (December 1941 to July 1943)* (Washington,: Office of the Chief of Military History Dept. of the Army, 1957), 98.
[2] Congress, *Hearings Before the Investigation of the Pearl Harbor Attack, Congress of the United States, Seventy-Ninth Congress, Part 10* (United States Government Printing Office, Washington, 1946), 5036-5037.
[3] C. L. Grant, *USAF Historical Studies: No. 126 the Development of Continental Air Defense to 1 September 1954* (edited by USAF Historical Division Research Studies Institute: Air University, Maxwell AFB, Alabama), ix.
[4] Stetson Conn, *Guarding the United States and Its Outposts*, 62.
[5] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 24.
[6] Conn, *Guarding the United States and Its Outposts*, 80.

268s. Of these, 31 SCR-270s and 127 SCR-268s were located on the Pacific coast and the rest on the Atlantic.[7] By early 1943, the continental air defense system went into standby mode when it became clear an attack by Germany or Japan was unlikely. By April 1944, the Joint Chiefs of Staff deemed the threat to the United States nonexistent and inactivated the entire air defense system. Fighter control procedures, established for the continental air defense, although never tested, formed the basis for American command and control doctrine.[8]

Organization

Air Defense Doctrine

While the US took steps to establish a unified and competent air defense (command control*) system, it did not do so quickly enough. Pearl Harbor increased the speed of unit training and highlighted the criticality of command and control for effective operations, not just defensively, but also offensively. Before operations in the Mediterranean, the AAF used radar mainly for reporting, filtering, and plotting aircraft information. It also parceled out aircraft to ground units. After its initial experiences in North Africa and exposure to British methods, it focused more on controlling aircraft. The move was due to a shift in mindset from defensive to offensive operations, adaptation to fluid and dynamic situations on the battlefield, and an increased understanding of the potential of new technology that moved fighter control away from defensive-only operations.[9] The work done across the AAF developing command and control procedures for air defense set the foundation for the command and control processes used in the combat theaters and the offensive operations required to defeat the Axis powers. Several

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[7] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 290.
* The term command and control did not exist before World War II. The term command control evolved into command and control by the end of the war.
[8] Grant, "USAF Historical Studies: No. 126 the Development of Continental Air Defense to 1 September 1954," ix.
[9] "Radar at the Front," 9, 15.

foundational documents began to finally appear in 1942, more than six months after Pearl Harbor.

The first, *Signal Corps Field Manual FM 11-25, Aircraft Warning Service*, August 3, 1942, described the Aircraft Warning Service's mission, responsibilities, and functions, covering and consolidating many of the concepts learned and executed during all Army exercises since WWI. It established the air force commander as the air defense commander and the interception command, later the fighter command, as the organization responsible for air defense in a region. Finally, the manual covered procedures to integrate radar and ground observer data, how to filter and plot data, and the duties of the controller conducting the intercept. It was a how-to for the Air Warning Service.[10]

Changes to *Army Regulation 95-5, Army Air Forces, General Provisions* in 1941 charged the Commanding General of the Army Air Forces with active defense of the US.[11] *Army Air Forces FM 1-25, Air Defense*, dated 24 December 1942, the first ever unified Air Defense publication, required field commanders to make air defense plans using the policy and methods established by the Army Air Forces. The Commanding General of the AAF was responsible for fighter aircraft and air warning instruments while responsibility for AAA, searchlights, and barrage balloons rested with the Ground Forces Commanding General. The Commanding Generals of Air Defense Commands were responsible in war for executing air defense.[12] For the first time, an Army publication clearly designated the lines of command and control for air defense.

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[10] *Signal Corps Field Manual FM 11-25, Aircraft Warning Service*, August 3, 1942.; AAFSAT Course Lecture, "Introduction to Course in Basic Control," February 1944, Call # 248.25-1, in the USAF Collection, AFHRA, Maxwell AFB AL.

[11] War Department, *Army Regulation No. 95-5, Army Air Forces, General Provisions*, June 20, 1941 (War Department, Washington), Call # 170.109095-5, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[12] War Department, *FM 1-25 Army Air Forces Field Manual Air Defense*, 24 Dec 1942 (War Department: Washington).

The Fighter Commands in a theater of war controlled all mobile and fixed AWS units thus achieving unified command of pursuit, AAA, searchlights, barrage balloons under a fighter commander. The commander had the flexibility to display information "in a manner adapted to meet the needs of the command and control system." Responsibility for strategic placement of AAA and searchlights in accordance with the defensive plan also belonged to the fighter commander. *FM 1-25 Air Defense* described the division of the US into regions, then filter areas, and finally into raid warning districts. Concepts such as local and area defense, ground alert, air alert, search patrol methods, a Ground Observer system, and filter rooms all received attention in the manual. Finally, the publication vaguely addressed "instrumental" means of detection—radar.[13] This 12-page document finally captured the basics of a command and control system, albeit only one for air defense, but its concepts served as the building block for the command and control of American air power.

Just six months later, the Army Air Forces released an updated *Army Air Forces FM 1-25 Air Defense*, 15 June 1943, with some significant changes. First, while the responsibility for all commanders to provide air defense did not change, now it would normally be "delegated to the fighter commander through the air force commander *within an air defense area prescribed by the theater of operations or similar commander. Ground units of the field forces outside of the air defense area are responsible for providing local antiaircraft artillery protection through the fire of assigned or attached antiaircraft units*." This concept grew out of experiences in North Africa and reflected the American acceptance of the notion Churchill prescribed to his armed forces in September 1941, that air power cannot continuously provide protection to ground forces.

[13] War Department, *FM 1-25 Army Air Forces Field Manual Air Defense*, 24 Dec 1942 (War Department: Washington).

Second, the manual added definitions for an Air Defense Wing, air defense regions, and AAA intelligence service. It also more clearly defined fighter control areas, the Aircraft Warning Service, and AAA, placing the later under the Fighter Command. Finally, the new manual prescribed tactical coordination and employment procedures.[14]

While wrapped in the title of Air Defense, these manuals served as the doctrinal foundation for a command and control system. Combat operations in North Africa and then Europe combined the growing capabilities of radio, mobility, and air-ground integration to create a robust command and control system that still exists today in almost the same form.

Air-Ground Cooperation Doctrine

General Arnold stated, "It is the team of the Army, Navy, and Air Forces working in close cooperation that gives strength to our armed services in peace or war."[15] This statement best exemplified air-ground cooperation in World War II, although it did not begin that way. He went on, "The first combat action by American troops was not well executed, but many lessons and ideas about the Tactical Air Forces evolved in the heat of these [North African] desert campaigns."[16] The story and details of Operation Torch, begun in November 1942 is well known.

Doctrinally, the US executed Operation TORCH with four additional field manuals besides the newly released *FM 11-25, Aircraft Warning Service* that related to the execution of air power; FM 1-15, FM 1-10, FM 1-5, and FM 31-35. FM 100-20 followed afterwards from the lessons of Operation TORCH.

FM 1-15, Tactics and Techniques of Air Fighting, released on September 9, 1940 and again on April 10, 1942, served as a TTP manual

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[14] War Department, *FM 1-25 Air Defense*, 15 June 1943 (War Department: Washington).

[15] H. H. Arnold, *Third Report of the Commanding General of the Army Air Forces to the Secretary of War: 12 November 1945* (Washington D.C.:, 1945), 62.

[16] H. H. Arnold, *Report of the Commanding General of the Army Air Forces to the Secretary of War: 4 June 1944* (Washington D.C.:, 1944), 41.

for pursuit aircraft. From a command and control perspective it addressed the use of an aircraft warning service, interception procedures, and the use of pursuit aviation to protect air support aircraft.[17] *FM 1-10, Tactics and Technique of Air Attack*, November 20, 1940, covered the use of bombardment aviation, attack methods, and attack planning and operations, thus addressing the air support side of air operations. It specifically addressed the direct support of armor, the use of radios, liaison between air and ground forces, and the use of panels for marking and other communications methods. The manual did not reference control parties or Air Support Commands.[18]

FM 1-5, Employment of Aviation of the Army, January 18, 1943, outlined the overall organizational structure and missions of the air forces, to include command and control of air forces by the Commanding General, Army Air Forces, and the command and control of air forces under other commanders. Unlike *FM 1-10, FM 1-5* addressed air support commands, stating, "The air support commander is charged with the responsibility for the maximum support of the plan of the supported ground commander." Centralized command and decentralized execution by the ASC maximized the ground commander's ability to make air requests. The air support commander was to advise the Army commander, collocate headquarters, and exchange liaisons to each other's headquarters. While not mandating first, second, and third priority missions, the manual listed general mission priorities as air superiority, deeper operations, and then directly against land and sea forces. Finally, it addressed air defense needs with either a fixed or a

[17] War Department, *FM 1-15, Tactics and Techniques of Air Fighting*, April 10, 1942 (War Department: Washington).
[18] War Department, *FM 1-10, Tactics and Technique of Air Attack*, November 20, 1940 (War Department: Washington).

mobile aircraft warning service in order to guarantee ground force freedom of action.[19]

The Army issued two training circulars signed by General Marshall after the Ft Benning Exercise held in June 1942 and before the release of *FM 31-35, Aviation in Support of Ground Forces* in August 1942; Training Circular (TC) 36, dated June 16, 1942, and TC 37, 29 June 1942. TC 36 clarified points of contention during preparation for operations in Europe and the Pacific. The circular addressed the centralized control, decentralized execution of airpower to meet the needs and requirements of the supreme commander. Drawing upon lessons from the latest exercise at Ft Benning, it stated that some ground units would get support, and some would not, depending on the ground scheme of maneuver. Second, it reiterated the assignment of observation aircraft to air support commands and that information from these aircraft should flow directly to the supported unit and to the air support command headquarters for dissemination. Finally, observation should only attack as a last resort since its primary function is observation.[20]

Many Army commanders expected 24-hour airpower support. TC 37 expounded on "air alert" and the perils of maintaining it due to an aircraft's finite loiter time and required maintenance. It also attempted to correct the impression that air would always be available. Like TC 36, it reiterated the importance of centralized control. Finally, the circular stated that the equal distribution of airpower was not sound, highlighted the importance of massed firepower, and reaffirmed that aircraft allocation cannot be normalized. An estimate of the situation determined the appropriate allocation.[21]

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[19] War Department, *FM 1-5, Employment of Aviation of the Army*, January 18, 1943 (War Department: Washington).
[20] War Department, *Training Circular No. 36* (War Department, Washington, June 16, 1942), Call # 168.607-30, in the USAF Collection, AFHRA, Maxwell AFB AL.
[21] War Department, *Training Circular No. 37* (War Department, Washington, June 29, 1942), Call # 168.607-30, in the USAF Collection, AFHRA, Maxwell AFB AL.

The final manual developed by air and ground forces before the US's first combat action was *FM 31-35, Aviation in Support of Ground Forces*, April 9, 1942. FM 31-35 described the "organization for combat, general functions and employment aviation used in tactical support of ground forces." The manual addressed an air support command, air support control, air support officers, and air support parties. Mirroring TC 36 and TC 37, FM 31-35 addressed the centralizing of airpower under the air support commander. Only when required should air be allocated to subordinate ground units. These circumstances however, were viewed as exceptional. Events in North Africa proved otherwise, and required the release of FM 100-20 to enforce the coequal status and centralized control of airpower concept. Airpower had many missions; it was not simply flying artillery as many in the Army thought. Organizationally, the concept of an ASC tied to an Army headquarters and with control parties at the Corps and Divisions remained in place throughout the war.

FM 31-35 prescribed that targets selected should not be "within the effective range of the weapons of ground forces," rather targets should be forces and infrastructure further afield. It also addressed air request procedures, communications, and troop identification. The manual was sound, but was not forceful enough in preventing the parceling of airpower, making all the concepts previously enshrined and practiced moot.

As already discussed, poor execution and results in North Africa coupled with British influence led to changes in American doctrine and the release of *FM 100-20, Command and Employment of Air Power*, 21 July 1943. FM 100-20 made air and land power co-equal and stated, "Air superiority is the requirement for the success of any land operation." It emphasized centralized control of air power and made an air and ground component report to a joint or superior commander that was not to attach air forces under ground units except in very rare situations. Finally, it addressed first (air superiority), second (interdiction), and third (close air support) priority missions, mirroring the British concepts. FM 100-20 provided the final doctrinal foundation for the creation of an airpower command and control system.

Preparation

General H. H. Arnold, Commanding General, Army Air Forces stated, "The personnel of the Army Air Forces must know as much as possible about radar, and make the greatest possible use of both their knowledge and their equipment, for the perfectly simple reason that by doing so they will be able to fly better, fight better and deal with the enemy more effectively in general."[22] The Air Corps took General Arnold's words seriously with the creation of the Army Air Forces School of Advanced Tactics (AAFSAT).

Army Air Forces School of Advanced Tactics

The need for all available personnel for the war effort led to ACTS suspending operations in spring 1940. ACTS taught more than theory. It also conducted experiments and exercises. Operational units had to close the gap left by the school's closing. Testing weapons, equipment, and procedures, including fighter and command and control tactics, fell on operational units until AAFSAT's creation in Orlando, Florida on 12 November 1942. Upon its establishment, AAFSAT became responsible for developing air force tactics. It was at AAFSAT that, "the procedures and control procedures used in the Sicilian landings" were tested. Other areas taught included bombardment, observation, and attack. It became the Army Air Forces Tactical Center (AAFTC) in October 1943.[23]

The growing importance of fighter aircraft and command and control resulted in the creation of a Fighter Command School in Orlando in February 1942. The Fighter Command School became AAFSAT's Air

[22] "In This Issue," *Radar*, no. 1 (April 1944).

[23] *Army Air Force Historical Studies No 13, The Development of Tactical Doctrine at AAFSAT and AAFTAC* (Prepared by Assistant Chief of Air Staff, Intelligence, Historical Division, July 1944), 1, 6, 8,22, 25; H. H. Arnold, *Report of the Commanding General of the Army Air Forces to the Secretary of War: 4 June 1944* (Washington D.C.:, 1944), 15-16.

Defense Department upon its establishment. The school already had radar and radio facilities and the only place to conduct fighter-searchlight training in the US.[24] AAFSAT's Air Defense Department quickly developed from nothing to become a busy training center for fighter controllers, pilots, and AI operators in fighter control methods. It established training syllabi on its own and in collaboration with the British. British instructors also served at the school to teach fighter control methods and provided the school with its first fighter control syllabus.

Based on his extensive experience, Brigadier General Gordon P. Saville became the director of Tactical Development at AAFSAT and a member of the AAF Board on 17 April 1943.[25] This board determined which weapon systems to development and it replaced the old Air Corps Board. Almost immediately, the school began solving several tactical problems such as developing lightweight radars for use during amphibious landings.

By the end of 1943, AAFSAT identified several deficiencies and limitations confronting fighter control. This included the number of scopes available, the ability of controllers, and the need to shift from defensive to offensive operations. A GCI station with one control position limited to one the number of night fighters a controller could effectively vector to its target. It also meant either control or reporting could be carried out, not both simultaneously. Simply adding more GCI positions did not solve the problem due to the limited number of SCR-588 consoles. The school determined three GCI positions maximized reporting and control. This resulted in not completing every mission or meeting

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[24] *Army Air Force Historical Studies No 13, The Development of Tactical Doctrine at AAFSAT and AAFTAC,* 25.

[25] *Army Air Force Historical Studies No 13, The Development of Tactical Doctrine at AAFSAT and AAFTAC,* 30-31.

every commander's request. Limited resources required priorities to be established.[26]

Controllers usually handled a single intercept, but experiments conducted at AAFSAT in March 1943, proved a controller could simultaneously deal with two interceptions with night fighters. The British followed up with similar results in May 1943 from their Operational Research GCI center located at Sturminster-Marshall. The British also reported a controller over North Africa had "conducted 3 interceptions in various stages at once. He thus caused the shooting down of four aircraft in ten minutes." This accomplishment was obviously extraordinary, but experiments in America and Britain highlighted how proper equipment, in-depth training, and experience (experienced instructors accomplished the experimental intercepts) could potentially maximize Allied fighter control capabilities.[27] Field units and the school worked on tactical problems together. Instructors going from the field to the school and from the school to the field throughout the war created an effective feedback loop.[28]

Exercises and Maneuvers

Exercises and maneuvers continued after Pearl Harbor. Unlike the maneuvers in 1941, the Air-Ground Demonstration at Fort Benning, 11-13 June 1942 integrated air power, served as the last major training exercise before American forces entered battle in North Africa, and attempted to closely follow the prescripts in *FM 31-35, Aviation in Support of Ground Forces*. The exercise highlighted many of the same lessons that air and ground forces later took from its North African experience.

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[26] Report, "Final Report of Standard Layout for Fixed Type GCI Station (SCR-588)," (AAFSAT, Fighter Control Division, October 12, 1943), Call # 248.252-30, in the USAF Collection, AFHRA, Maxwell AFB AL.
[27] "Final Report of Standard Layout for Fixed Type GCI Station (SCR-588)"
[28] *Army Air Force Historical Studies No 13, The Development of Tactical Doctrine at AAFSAT and AAFTAC*, 81-82, 88.

Participants, both air and land officers, believed in the overall correctness of FM 31-35 directing Air Support Parties (ASP) to provide air power advice, which was deemed essential to the ground force commander. They advised against the concept of "Air Demand Units," which were units with aircraft set aside to respond to the ground commanders needs. It did however recommend revising FM 31-35 to better explain ASP and Air Control duties, communications, air order data details, and the handling of air requests.[29]

A major lesson was the lack of knowledge, especially from ground commanders and officers regarding air power capabilities and the already entrenched Army idea a battalion commander can readily call airpower whenever required. The Army wanted to quell this notion. The report also recommended more training and education for Army officers specifically focusing on the details of air operations such as Air Control and Air Support Party processes. It also recommended creating an Assistant G-3 or G-3 Air with specific training, spending time in the Air Support Command, and flying. Conversely, it stated air ground operations required an officer more versed in air power than ground operations.[30]

Overall, ground and air needed to understand each other's capabilities, limitations, and methods of employment. The greatest lesson indicated the need to emphasize more joint air-ground training and the establishment of formal schools. This included an equal share of air planners at all levels to ensure proper employment of air power.[31]

At the tactical level, the exercise report recommended adding a vehicle to the ASP for mobility, to include the proper communications equipment. Participants thought most air support requests would be pre-planned targets because they required the least amount of real time

[29] Report. "Critique of Air-Ground Demonstration at Ft Benning, June 11-13, 1942," Call# 165.607-30, pp. 40, 56, in the USAF Collection, AFHRA, Maxwell AFB AL.
[30] Ibid, pp. 40, 56-57.
[31] Ibid, pp. 1, 56-57.

coordination and expected close support to be rare. Participants realized the complexity of executing impromptu air requests. Finally, they found phase lines as the only effective way to track friendly troops.[32]

The Fighter Control Group and Air Support Commands

The Fighter Control Squadron

The American command and control system had two distinct parts, as did the British and German. One focused on air-to-ground operations, the second on air-to-air operations. A discussion of the organizational structure and processes used in the air-to-ground command and control system follows. Over time, especially in northern Europe, the two systems blended to become seamless.

In the air-to-air command and control system, the Fighter Control Group served as the organization charged with the command and control of fighter aircraft for defensive and offensive air-to-air operations. Each TAC had a Fighter Control Group. The Fighter Control Squadron and the Air Warning Signal Battalions served as the two subcomponents of the Fighter Control Group. The Fighter Control Squadron (FCS) served as the basic tactical unit to control aircraft. Twenty-four officers and 222 enlisted served in four sections (headquarters, communications, security, and control) and executed eight functions. These eight functions included intercepting hostile aircraft, passing information on hostile positions, controlling aircraft for convoy cover, controlling aircraft for air-sea rescue, controlling aircraft for patrols, controlling fighters for escort missions, providing homing service for aircraft, and controlling fighters for sweep and attacks on enemy concentrations and communications.[33]

[32] Ibid, pp. 40, 57-58.
[33] AAFSAT Course Lecture "Structure of Fighter Control Squadron and Function in Strategic Operations," March 1944, pp. 1, 3, Call# 248.25-4, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report, "A Report on the Combat Operations of the XIX Tactical Air Command," (Headquarters, XIX Tactical Air Command, 30 May 1945), p. 2, Call # 168.607-35, in the USAF Collection, AFHRA, Maxwell AFB AL.; AAFSAT Course Lecture, "Fighter Control in the Tactical Air Command," March 1946, pp. 1-2, Call # 248.25-6, in the USAF Collection, AFHRA, Maxwell AFB AL.; "Radar at the Front," 9.

Initially the Fighter Control Squadron emerged to control air defense assets. Soon new functions emerged to include offensive operations, convoy patrol, air-sea rescue, and defense of bomber bases and communications. Using the established command and control infrastructure created for defensive operations, the Air Forces transitioned from defensive operations to offensive operations to gain local air superiority and attack enemy troop concentrations and communications equipment.[34]

The Aircraft Warning Service

The Signal Aircraft Warning Battalions (SAWB), a part of the Signal Corps, made up the second organization in the Fighter Control Group and worked closely with the Fighter Control Squadrons. Each SAWB had approximately 1,000 personnel and four branches: radar, ground observer corps, communications section, and filter center. "The battalions provided radar location, "friend or foe" identification, and visual front-line ground observer information to the Air Corps controllers located at the radar sites, and at the TAC operations centers where command decisions and aircraft dispatch orders originated." A SAWB consisted of 4 reporting companies, a HQ company, and 15 radars. Each SAWB helped control up to nine squadrons of aircraft.[35]

Air Support Commands

Air Support Commands (ASC), the primary organizational element for air-ground operations, coordinated all air activity to support the ground forces and acted as a clearinghouse for information. They advised through liaisons, controlled all air activity, and operated as a full

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[34] AAFSAT Course Lecture, "Structure and Function of a Fighter Control Squadron," February 1944, p. 2, Call # 248.25-4, in the USAF Collection, AFHRA, Maxwell AFB AL.

[35] AAFSAT Course Lecture "Orientation-The Air Defense System," May 1944, p. 6, Call # 248.25-25, in the USAF Collection, AFHRA, Maxwell AFB, AL.; William L. Freienmuth, "What did the WWII Signal Aircraft Warning Battalions in the ETO do?" (August 2008).; AAFSAT Course Lecture, "Fighter Control and Air Warning in France," 1944-1945, Call # 248.25-11, in the USAF Collection, AFHRA, Maxwell AFB, AL.

member of the Army unit to which attached. ASCs are discussed in more detail later.

A robust tactical air command and control organizational structure existed by the end of the war. The Theater Air Commander owned all aircraft in a theater with the Tactical Air Forces controlling all aircraft assigned to it. Subordinate to the Tactical Air Forces, the Tactical Air Divisions had Tactical Control Groups that controlled aircraft in the air through the Tactical Control Center (TCC) or Fighter Control Center (FCC).[36] TCC or FCCs were air command posts that managed all aircraft assigned to it, maintained the "air picture," and conducted tactical control of the aircraft.

Processes

Fighter Control Procedures

While the TACs relied on developments across the Army Air Forces, no standard operating procedures existed between the tactical air commands; either between Twelfth AF and Ninth AF, or within Ninth AF. TACs had the ability to create and change procedures depending on the environment and their situational needs. The basic processes however were the same. The FCC or TCC, maintained a centralized air picture, conducted offensive operations, and exercised operational control of anti-aircraft artillery and defensive fighters. The FCC became the nerve center for tactical air operations. General Quesada, IX TAC commander, "called the plotting board in the Fighter Control Center his 'air situation map' since he could view the board and find out what groups were operating where."[37] The FCC had 10 control positions.[38]

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[36] AAFSAT Course Lecture, "Offensive Control," February 1944, p. 1, Call # 248.25-1, in the USAF Collection, AFHRA, Maxwell AFB AL.
[37] Report, "A Report on the Combat Operations of the XIX Tactical Air Command," (Headquarters, XIX Tactical Air Command, 30 May 1945), p. 2, Call # 168.607-35, in the USAF Collection, AFHRA, Maxwell AFB AL.; AAFSAT Course Lecture, "Fighter Control in the Tactical Air Command," March 1946, pp. 1-2, Call # 248.25-6, in the USAF Collection, AFHRA, Maxwell AFB AL.
[38] "Fighter Bomber Control: A Compilation of Procedures Used by the Ninth Air Force During Operations on the European Continent," p. 12, Call # 168.601-34, in the USAF Collection, AFHRA, Maxwell AFB AL.

FCCs had several subordinate units. The first was the Microwave Early Radar (MEW), discussed later. FDPs connected to the MEW had smaller radar sets, including a Close Support Control unit with 2 SCR-584 radars. They increased radar coverage, controlled aircraft assigned to them by the FCC when the MEW reached capacity, and provided very accurate close control for ground attack aircraft. Ground observer posts and Lightweight Radar connected to the FDPs via FM or HF radio and via radio and telephone line to the FCC. Finally, four D/F stations connected to the FCC by FM radio. These stations helped aircraft receive position fixes and had a range of about 120 miles.[39]

Early in the war, operators used radar mainly for reporting, filtering, and plotting aircraft information for defensive needs. Once offensive operations began, the command and control system focused more on controlling aircraft. The move was a result of a shift in mindset from defensive to offensive operations, adaptation to fluid and dynamic situations on the battlefield, and an increased understanding and potential of new technology that moved fighter control away from defensive only operations.[40]

Fighter control processes in combat theaters differed slightly from those established on the continental United States. In combat theaters, the Air Defense Command or Fighter Command Region was broken down into sectors with an FCC comprised of an AWS, day and night fighters, AAA, and centralized ground control. The Area Controller exercised operational control of air defense from either the Tactical Headquarters

[39] "Fighter Bomber Control: A Compilation of Procedures Used by the Ninth Air Force During Operations on the European Continent," p. 12, Call # 168.601-34, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report, "A Report on the Combat Operations of the XIX Tactical Air Command," (Headquarters, XIX Tactical Air Command, 30 May 1945), p. 2, Call # 168.607-35, in the USAF Collection, AFHRA, Maxwell AFB AL.; *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 372.
[40] "Radar at the Front," 9, 15.

or the FCC using the same filtering and plotting process as in the U.S,[41] whereby plotting and filtering occurred for display of all aircraft information, including those from adjacent sectors, on the operations status board.[42] The major difference on the European continent was the integration of the Y-service and the Microwave Early Warning radar. The vertical plotting board in the FCC displayed the data received from the MEW. If an Air Defense Command lacked a MEW, such as during the Mediterranean Campaigns, the SCR-527 (used for reporting or night fighting control), SCR-270 for long-range reporting radar, or an AN/TPS 1-B (Lightweight Mobile Radar), was integrated into the system. Cross telling of radar information occurred between areas and sectors.[43]

Long-range early warning radars first detected an enemy aircraft. In response, the Area Controller usually scrambled three night fighters to marshal at altitudes above and below the reported enemy aircraft altitude. The fighters then proceeded to planned areas, using ground beacons to maintain position in their area of responsibility.[44] Once enemy aircraft were within the 50-mile limit of the PPI, the fighters switched to a GCI controller to begin vectoring the fighter to the enemy aircraft based on the information provided by the scope data and the Craig Computer.[45]

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[41] AAFSAT Course Lecture "The Fighter Control System," Call # 248.25-2, in the USAF Collection, AFHRA, Maxwell AFB AL.

[42] AAFSAT Course Lecture "Structure of Fighter Control Squadron and Function in Strategic Operations," March 1944, p. 3, Call# 248.25-4, in the USAF Collection, AFHRA, Maxwell AFB AL.; AAFSAT Course Lecture, AAFSAT, "Fighter Control in the Tactical Air Command," March 1946, p. 3, Call # 248.25-6, in the USAF Collection, AFHRA, Maxwell AFB AL.

[43] AAFSAT Course Lecture "The Fighter Control System," Call # 248.25-2, in the USAF Collection, AFHRA, Maxwell AFB AL.; AAFSAT Course Lecture, AAFSAT, "Fighter Control in the Tactical Air Command," March 1946, p. 3, Call # 248.25-6, in the USAF Collection, AFHRA, Maxwell AFB AL.

[44] AAFSAT Course Lecture, "GCI- AI Team," January 1944, Call # 248.25-8, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report, "History & Background of Night Interception," 1940, Call # 248.252-24, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[45] AAFSAT Course Lecture, "GCI- AI Team," January 1944, Call # 248.25-8, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report, "History & Background of Night Interception," 1940, Call # 248.252-24, in the USAF Collection, AFHRA, Maxwell AFB, AL.

The controller acted as the eyes for friendly aircraft, using a two-way VHF radio to conduct the intercept with established R/T procedures, and giving the pilot directional, height, and speed instructions. Once the controller thought the target was within the fighter's AI range, he called "Punch" (almost time for contact). After the AI operator acquired the target, he called "Judy" and the pilot took over the intercept.[46] When returning to base, controllers gave weather and other pertinent information.[47]

Controller initiative played a role in making doctrinal changes on the battlefield. If missions appeared not to be going as planned, the controller would contact the flight on VHF and offer assistance. As was the case with IFF, at first pilots were reluctant to receive help, but as time passed, and they realized the critical information provided by controllers, this resistance faded. The MEW and SCR-584 played an important part in these proactive attempts to get fighters to a target area.[48] In France, MEW and SCR-584 crews received the daily field orders, tracked the flights as they appeared on the radar scopes, and plotted them on the board.[49] The SCR-584s provided direct support to situations they were aware of versus waiting for input from headquarters. This also improved communications.[50] After a mission with the SCR-584, the MEW or the FDP received the fighters for return to base.[51] During bad weather, MEW controllers controlled aircraft to a

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[46] AAFSAT Course Lecture, "GCI- AI Team," January 1944, Call # 248.25-8, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report, "History & Background of Night Interception," 1940, Call # 248.252-24, in the USAF Collection, AFHRA, Maxwell AFB, AL.; "The Nightfighters." *Radar*, no. 8 (20 February 1945).; AAFSAT Course Lecture, "Offensive Control," February 1944, p. 4, Call # 248.25-1, in the USAF Collection, AFHRA, Maxwell AFB AL.
[47] AAFSAT Course Lecture "Structure of Fighter Control Squadron and Function in Strategic Operations," March 1944, p. 6, Call# 248-25-4, in the USAF Collection, AFHRA, Maxwell AFB AL.
[48] "Radar to Fighter to Target," Radar, no. 7 (1 January 1945): 36-37.
[49] "Radar to Fighter to Target," 36.
[50] "Radar and the War in Europe," 45.
[51] "Radar at the Front," 15.

sector and handed over control to a SCR-584 controller to control them to the target area.[52]

Radar mobility brought not only the advantages of protection, but also problems. Radars required high ground not only for the best radar and radio coverage, but also for camouflage, physical security, and ease of landline maintenance.[53] Problems also emerged when radars moved during a fluid battle, took casualties, or were threatened with capture. Under actual conditions, the MEW was up and running 48 hours after withdrawal and could easily switch between offensive and defensive roles.[54]

To enhance operations and ensure standardization across not only the AAF, but between allies, fighter director code was standardized. The AAF released *FM 24-9, Combined United States-British Radio-Telephone (R/T) Procedure,* which contained certain procedures and *FM 1-46, Fighter Radiotelephone Procedures and Code*, which had specialized procedures for fighter control, while the allies between them released *CCBP 0123*, containing the agreed upon Fighter Director Code. Common procedures and code words improved effectiveness through uniformity, brevity, and security, thus reducing misunderstandings and improving interoperability with allies.[55]

Command and Control in the Strategic Air Forces

The majority of literature on strategic bombing operations tends to focus on the strategic operations of Eighth Air Force or the tactical operations of Ninth Air Force, focusing on unit actions, geographic movement, or impact to the overall war effort. Little exists on the command and control of strategic air forces, the processes, and

52 "Radar to Fighter to Target," 37.
53 "Final Report of Standard Layout for Fixed Type GCI Station (SCR-588)"; "Radar and the War in Europe," 45.; "What Happened in the Breakthrough," 6.
54 "What Happened in the Breakthrough," 5.
55 AAFSAT Course Lecture, "Radio-Telephone Procedure Principles and Use," February 1944, p. 2, Call # 248.25-1, in the USAF Collection, AFHRA, Maxwell AFB AL.

interaction between strategic and tactical air forces, or how a command and control system helped execute those efforts.

The strategic bombing effort against the Axis was a combined bombing effort. The RAF and AAF conducted joint planning to synchronize not only day and night bomber efforts of the Combined Bomber Offensive, but also fighter support, especially for AAF day missions. The RAF and AAF conducted joint planning using the Combined Operations Planning Committee (COPC). The committee included the Theater Commanders and G-2s, and Air Force, VIII Bomber Command, Air Ministry, RAF, and Royal Navy representatives. The COPC selected targets, priorities, and formulated the broad plans (main and diversionary), then sent them off to the Air Force Commander for approval.[56]

The following mission, conducted on 2 October 1943, demonstrates the command and control process used for strategic air forces. The plan directed 352 B-17s from VIII Bomber Command to hit Enden, Norway. The Committee planed five diversionary attacks to draw fighters away from the B-17s. They included 21 B-24s with Spitfire escort against a North Sea target, RAF Typhoons attacking shipping along the Dutch coast, RAF Hurricanes, Typhoons, and Spitfires patrolling Northern France, RAF Hurricanes, Typhoons, and Mustangs attacking targets in the Caen-Rouen area, and B-26s of VIII Air Support Command with Spitfires attacking a French airfield.[57]

Eighth Air Force sent orders to the B-17s of VIII Bomber Command and to the B-26s of VIII Air Support Command, while the RAF sent orders via its chain of command. VIII ASC issued field orders to the wings whose staff (A-2, A-3, weather, Wing Bombardier, Wing Navigator, and the Ordnance Section) worked the mission details, and coordinated

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[56] AAFSAT Course Lecture, "First Priority Mission TAF with the VIII Air Force," September 1944, pp. 3, 7, Call # 248.241-7, in the USAF Collection, AFHRA, Maxwell AFB, AL.
[57] Ibid, 3-4.

the escort size, time, and place with the RAF. The rendezvous was coordinated between fighters and bombers, orders typed on a completed plan, and then sent to all units involved.[58]

The B-26s timed their missions to coincide with those of the B-17s. With planning complete at the wing, it issued orders in a five-paragraph format to include the axis of attack, air points, radio frequencies, call signs, sector call signs, etc.[59] The five paragraph order followed this format:

I Friendly and Enemy situation

II The General Plan

III The Detailed Plan

IV Supply

V Communications

Paragraph I contained the missions flown that day, who will provide escort, and expected enemy action. Paragraph II described the general plan to include zero hour. Paragraph III provided information such as targets, aircraft required for each group, bomb load and fusing, rendezvous altitude, location, time, route in and out of the target areas, axis of attack and aim points. Paragraph IV for this mission had "no change," and Paragraph V provided aircraft call signs with frequency assignments for all the groups, fighter-bomber coordination frequency and, ground sector callsign.[60]

After the order arrived at the Group, the crew briefing occurred two hours before take off. After the crew briefing, the commander and his staff held a conference to determine "the exact axis of attack for each box, the spacing of bombs, the cruising speed enroute and over the target." Once completed, "the group operations officer teletyped the "J" form to the Bomb Wing," showing aircraft, call sign, bomb load, and fuel

[58] Ibid, 2-7.
[59] Ibid, 2-6.
[60] Ibid, 5-8.

load. The Group Commander, Group Navigator, and Intelligence Officer conducted the mission brief, followed by a pilot and co-pilot brief with the commander to discuss specific box tactics. Next, the crews finished take-off preparations, launched at 25-second intervals, and then followed their rendezvous plans. Radio beacons across England and later on the continent helped the B-17s rendezvous. Two and half-hours later, the crew landed and completed a mission debrief with Intelligence, Ordnance, and Communications. A preliminary report arrived at the Bomb Wing one hour after landing containing "hot" news and lost aircraft/aircrew details.[61]

A complete mission report folder followed the next day for the Commanding General of the Bomb Wing. The report had three parts, the A-3 Tactical Report, Report of Malfunctions of Equipment, and the Report of A/C Losses, Damage and Abortive on Operations. The A-3 Tactical Report summarized the mission data, bombing, enemy encounters, defensive gunnery, evasive action against flak, communication and equipment use and malfunctions, equipment failure, maneuvers at the IP and bomb run in, assembly and formations, and weather. The data contained in the other two reports is self-explanatory.[62]

After the lessons of late 1943 and the unacceptable bomber loss rates, the RAF and Eight AF fighters conducted fighter sweeps across the English Channel and began escorting bombers onto the continent. Eighth AF employed a shuttle system of escort with the P-47, P-51, and P-38s going 500 miles with the bombers. This coupled with diversionary attacks helped reduce bomber loss rates. Throughout 1943 and to mid-1944, Ninth AF also conducted diversionary missions on the continent in

[61] Ibid, 7.
[62] Ibid, 7.

support of Eighth AF, while the Eighth conducted tactical missions to assist Ninth AF.[63]

Allied fighters employed two methods of bomber escort; static or relay escort. Static had one set of fighters going to the target and back with the bombers while relay used successive fighters to provide cover depending on range and basing. With either static or relay escort, fighters used close cover or area cover. Area cover more aggressively attacked enemy fighters.[64] Initially, distance was an issue, but with the advent of drop tanks and airfields on the continent after June 1944, distance became less of problem. Aircraft used airborne relays for communications during long-range missions over Germany.[65]

For example, the 52 FCS, under 65 FW, and Eighth AF, controlled eight groups of Thunderbolts for bomber escort duties or during fighter sweeps. The standard VHF radio communication setup had four frequencies; Button A for fighter control, B for Air-Sea Rescue, C for relaying messages and interplane between fighter and bombers, and D for the D/F channel. The controller provided the fighter aircraft various information to include, bombers course, time, schedule, and data on every track on radar and "Y" source to include #, location, altitude and course of the enemy. Controllers forwarded fighters or bombers delays or mission changes affecting both fighters and bombers on "C" Channel. If necessary, such as during bad weather or when bombers flew off course, the lead controller provided vectors to the bombers.[66]

Command and Control before Operation TORCH

By the end of summer 1942, with FM 31-35 as guidance and the last major exercise at Ft Benning complete, the Army and Army Air

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63 Ibid, 2-3, 7, 10.

64 AAFSAT Course Lecture, "Employment of Fighter Escort on Bombing Missions," January 1945, p. 1, Call # 248.25-13, in the USAF Collection, AFHRA, Maxwell AFB, AL.

65 AAFSAT Course Lecture, "Fighter Control in Air Defense," June 1944, p. 4, Call # 248.25-2, in the USAF Collection, AFHRA, Maxwell AFB AL.

66 AAFSAT Course Lecture "Structure of Fighter Control Squadron and Function in Strategic Operations," March 1944, pp. 4-6, Call# 248-25-4, in the USAF Collection, AFHRA, Maxwell AFB AL.

Forces had a basic doctrine for air-ground operations to include the organizational structure, processes, and technology.

The Air Support Command, as the primary organizational element for air-ground cooperation, collocated its headquarters next to the Army headquarters to facilitate communication between the A-2/A-3 and the G-2/G-3. Each Corps headquarters had an Air Support Command and each Division headquarters had air support parties.

Air Support Control Officers located at Division and Corps had their own communication equipment and transportation. They integrated completely into the planning process, managed the flow of information between air and ground headquarters, and made the air plan for the Army, to include writing the air orders. The Army commander, however, decided the allocation of aircraft to Corps and Divisions based on the needs of the Army as a whole. Allocated aircraft consisted mainly of observation and ground attack aircraft. In 1942, the Army considered a change to the allocation during battle a result of poor planning.[67]

The air group designated to support each Corps and Division sent a liaison to the respective headquarters and reported to the support control officers to advise Corps and Division commanders on the allocation of their aircraft. Army ground liaisons assigned to airfields had similar requirements; they advised pilots on the ground situation and served as a conduit for information between air and ground headquarters.

When a subordinate unit, for example a Division, required air support, the request went from the unit commander to an air support party located at the Division headquarters. Requests consisted of 1)

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[67] Lecture, "The duties of an Air Support Control Officer," Conducted by Colonel Doyle, Headquarters I Ground Air Support Command, September 4, 1942, Call # 168.607-30, in the USAF Collection, AFHRA, Maxwell AFB.; Memorandum 55-4, "Standing Operating Procedures Communications Air Support Request Forms (Revised Copy), Headquarters III Ground Air Support Command, July 13, 1942, Call # 168.607-30, in the USAF Collection, AFHRA, Maxwell AFB, AL.

target type/designation, 2) location, 3) direction of movement, 4) target characteristics, 5) location of friendly troops, and 6) time limits of request The Corps/Division G-3 coordinated with the Air Support Control Officer and air support party for feasibility. If the division commander approved the request, the air support party forwarded it the Air Support Control Officer via radio. The Corps G-3 either approved or disapproved the request. If approved, the aerodromes received notification and aircraft launched. The Army commander, listening on the net, could also disapprove if the request did not support his scheme of maneuver. Once the aircraft completed a mission, a mission debrief occurred with the ground liaison at the aerodrome.[68] The US executed its first operations of the European theater with this system in place.

Command and Control after Operation TORCH

The lack of effective air power in general and air-to-ground operations in particular was touched upon earlier. Air Marshal Coningham's arrival as the Allied Air Support Command, later North Africa Tactical Air Forces commander, coupled with formal doctrinal changes expressed in the release of FM 100-20 resulted in changes to the air-to-ground command and control system. The British required political direction to solve airpower's role, while the Americans required a combination of battlefield exposure, British influence, and political direction.

The XII Air Support Command, after April 1944 known as XII Tactical Air Command, initially operated with Seventh Army, was later reassigned to work with Fifth Army before Operation AVALANCHE. While XII ASC located its Air Support section next to Fifth Army Headquarters, XII TAC, Combat Operations, and the Tactical Control Center were

[68] Memorandum 55-4, "Standing Operating Procedures Communications Air Support Request Forms (Revised Copy), Headquarters III Ground Air Support Command, July 13, 1942, Call # 168.607-30, in the USAF Collection, AFHRA, Maxwell AFB, AL.

located at 64th Fighter Wing Headquarters,[69] usually 5-40 miles behind the bomb line.[70]

XII ASC sent one Air Party officer (usually a major or lieutenant colonel) to the Division and two to the Corps Headquarters. Their duties included: 1) transmitting air attack requests, 2) passing information on the bomb line, 3) recording mission results, 4) passing relevant ground data to air force headquarters, and 5) if qualified, acting as a special advisor to the ground commander.[71]

Planning against targets fell into two categories, scheduled or pre-planned and targets of opportunity or on-call, divided 80% and 20% respectively, although by the end of 1944 scheduled targets approached 95%. Scheduled target planning began with the Division submitting to the Corps their requests for the next day. After prioritizing, adjusting, or cutting to conform to the next day's scheme of maneuver, the plan went to the Air Support Control section at Fifth Army. The ASC evaluated the plan in preparation for the daily Army-Air conference, where the Army G-3 and TAC A-3 ordered the priorities based on available assets. At the conference, the Air Support Control officers presented the requests. The Army G-3 followed with a brief on todays and the next day's ground scheme of maneuver with the A-3 following. Air and ground officers worked through any issues and the final agreed upon plan was the daily Air Support Plan. XII ASC only had fighter-bombers and any need for medium bomber support required a request to the TAF. Fifteenth Army

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[69] *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 370.; *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, p. 53, Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[70] AAFSAT Course Lecture, "Structure and Function of a Fighter Control Squadron," February 1944, p. 6, Call # 248.25-4, in the USAF Collection, AFHRA, Maxwell AFB AL.

[71] AAFSAT Course Lecture, "Air Ground Coordination or Cooperation System between Air and Ground Forces," February 1944, p. 6, Call # 248.241-16, in the USAF Collection, AFHRA, Maxwell AFB, AL.;

Group and TAF HQ followed a similar process for approval of these assets.[72]

The ground commander determined the bomb line.[73] Once airborne, the bomb line had to be clearly visible to the pilot in order to avoid fratricide. The air party, in coordination with its assigned ground unit, visually marked the bomb line with yellow smoke, flares, Very pistol (same as used in WWI), artillery, or panels.[74]

An airborne controller contacted the Air Liaison Officer, usually in an armored car, and received the latest updates on ground events. The airborne controller could divert aircraft as necessary and had the ability to stay in contact with TAF HQ. Despite the ability to dynamically adjust aircraft to changes on the ground situation, ensuring proper synchronization required a lot of preplanning.[75] This process was extremely critical when engaging targets of opportunity.

Against targets of opportunity, the Division G-3 requested support on a target. The Air Party at division radioed the request to the Army Air Support Control (AASC) section, located next to the G-3 Operations tent and General Brann's trailer. The Corps, listening on the same radio network, had the option of cancelling the request if not in accordance with its plan. AASC checked the target against the bomb line and approved it if the mission supported the overall scheme. In this case,

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[72] AAFSAT Course Lecture, "Air Ground Coordination or Cooperation System between Air and Ground Forces," February 1944, p. 6, Call # 248.241-16, in the USAF Collection, AFHRA, Maxwell AFB, AL.; AAFSAT Course Lecture, "Mission Control and Liaison," January 1945, Call # 248.241-3, in the USAF Collection, AFHRA, Maxwell AFB.; AAFSAT Course Lecture, "Mission Control and Liaison," April 1945, Call # 248.241-3, in the USAF Collection, AFHRA, Maxwell AFB.;

[73] AAFSAT Course Lecture, "Air-Ground Coordination and Planning, 18 November 1943, p. 1, Call # 248.241-1, in the USAF Collection, AFHRA, Maxwell AFB, AL.; AAFSAT Course Lecture, "Air Ground Coordination or Cooperation System between Air and Ground Forces," February 1944, p. 5, Call # 248.241-16, in the USAF Collection, AFHRA, Maxwell AFB, AL.;

[74] AAFSAT Course Lecture, "Tactical Bomber Operations in the ETO," June 1944, p. 1, Call # 248.241-6, in the USAF Collection, AFHRA, Maxwell AFB, AL.; *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, "Amendments to SSI Number 1, Item No. 2, dated 12 June 1944, 17 January 1944 from Headquarters XII Air Support Command," Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[75] AAFSAT Course Lecture, "Tactical Bomber Operations in the ETO," June 1944, p. 1, Call # 248.241-6, in the USAF Collection, AFHRA, Maxwell AFB, AL.;

General Brann approved every request personally and if he was not available then the G-3 Duty Officer had the responsibility. The A-3 approved or disapproved from the air perspective. With the mission approved, the AASC sent the information to XII Air Support Command for execution and the TAC sent the information to the flying unit. While this process executed, a Ground Liaison Officer also received the target information and began face-to-face preparation with the pilots to save time. Once the time over target was determined, the information traveled back down the system to front line troops. Overall, 50% of the requests were refused; 75% for not being part of the Army plan and 25% for Air Support Command reasons, to include weather or other technical reasons. The average time for requests was approximately 50 minutes by the later part of 1944.[76]

The Army established the communication infrastructure between the two rather than the Air Force, as was the standard across other theaters.[77] The ASC provided a skilled observer, usually a fighter pilot with combat experience, to provide airborne aircraft with an accurate and safe ground picture to employ weapons.[78] ASCs employed "Rover Control" when necessary to "talk a plane in.” Rover was simply the term given to the mobile controllers in vehicles. A highly qualified pilot accomplished this mission (usually an Assistant A-3 at the TAC HQ) via VHF radio on a Jeep.[79] Airborne observers with radios provided connectivity between aircraft and ground forces.[80]

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[76] AAFSAT Course Lecture, “Air Ground Coordination or Cooperation System between Air and Ground Forces,” February 1944, p. 7, Call # 248.241-16, in the USAF Collection, AFHRA, Maxwell AFB, AL.; AAFSAT Course Lecture, “Mission Control and Liaison,” January 1945, Call # 248.241-3, in the USAF Collection, AFHRA, Maxwell AFB.;

[77] AAFSAT Course Lecture, “Air Ground Coordination or Cooperation System between Air and Ground Forces,” February 1944, p. 5, Call # 248.241-16, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[78] AAFSAT Course Lecture, “Air-Ground Coordination and Planning, 18 November 1943, p. 3, Call # 248.241-1, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[79] AAFSAT Course Lecture, “Mission Control and Liaison,” April 1945, p. 1, Call # 248.241-3, in the USAF Collection, AFHRA, Maxwell AFB.;

[80] AAFSAT Course Lecture, “Air-Ground Coordination and Planning, 18 November 1943, p. 4, Call # 248.241-1, in the USAF Collection, AFHRA, Maxwell AFB, AL.

The Tactical Air Forces (TAF) commander accomplished the target selection in the early phases of operations for photography, reconnaissance, and ground force intelligence requirements. Target selection and planning required coordination with the Army and Navy as the campaign progressed. Depending on the level of planning, the TAF or Air Division commander conducted target selection with Army Group or Army commander input rather than with Division or Battalion input to ensure alignment with theater level objectives. Centralizing planning at a higher command level maximized airpower based on the small number of fighters and bombers available. As is the case today, this resulted in many troops at lower levels not understanding why they never received air support.[81]

By the summer of 1943, a more robust command and control system existed as the allies prepared for operations into Sicily and Italy. The processes and technologies established for air defense and air-to-ground operations parlayed into effective methodologies for conducting amphibious landings.

Operations HUSKY-AVALANCHE-SHINGLE

Experience in North Africa drove changes that improved operations for the Tunisian Campaign and the landings in Sicily (Operation HUSKY). The Allies however, met very little resistance to their landings on Sicily and for the Americans there was very little close air support in Sicily due to a very rapid ground advance.[82] The Allies however, effectively used the lessons and improvements after Operation TORCH during Operation HUSKY and especially against German and Italian resistance during the landings on the Italian mainland during Operations AVALANCHE and SHINGLE.

[81] AAFSAT Course Lecture, "Air-Ground Coordination and Planning, 18 November 1943, pp. 5, 7, Call # 248.241-1, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[82] United States, *USAF tactical operations, World War II and Korean War with statistical tables* (Washington, D.C., USAF Historical Division, Liaison Office, 1962), 14.

For Operation AVALANCHE all aircraft remained under the control of a central operations room operated by No 1 Mobile Operations Room Units (MORU), the main British tactical control unit. Two controllers from the 64 Fighter Wing (FW) operated from the MORU with their own equipment to control 64 FW aircraft. Fighter aircraft operated under ship control during the amphibious landing phase until the 64 FW established its FCC ashore. The RAF sent two controllers to the 64 FW FCC ashore with their own communications equipment to control RAF aircraft. A RAF senior controller also operated from the ship before moving ashore with the 64 FW to ensure continuity of operations. Night fighter control however continued from the ship until GCI equipment became operational ashore.[83]

The 64 FW FCC Ashore arrived via LST with one GCI, two LW sets, Ground Observer Posts, and a "Y"-Service Detachment. Then at D+5, another LST delivered a GCI and two LW sets. Once established ashore, fighter control transferred from the ship to the 64 FW FCC. [84] Close liaison between the Navy and XII ASC ensured a smooth transition of fighter aircraft and the ability to counter German jamming since the LST could move along the shore making its location difficult for the Germans to pinpoint.[85] Procedurally, fighters checked in and out with the ship or

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[83] *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, "Operational Directive for Operation 'AVALANCHE' No. 1, From Headquarters Tactical Air Forces, 17 August 1943, To: Commanding General, XII Air Support Command," Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL.
[84] *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, Operations "SHINGLE" Operation Instruction No. 1, Headquarters Mediterranean Allied Tactical Air Force, 19 January 1944," pp. 3-4, Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL.
[85] *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, HQ Northwest African Tactical Air Force Letter to Commanding General, XIII Air Support Command, 30 December 1943, "Operational Directive for Operation "SHINGLE" No. 1," Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL.

FCC via VHF and then to a GCI controller, located either on a ship or ashore.[86] TTPs had two fighters utilizing GCI and two "free lancing."[87]

During this phase of the war, the allies were extremely concerned about the security of sensitive technology, and night fighters over Italy equipped with the Mark VIII AI were not authorized to fly within 10 miles of enemy lines to prevent the equipment from falling into German hands as the Mark III had earlier in the war.[88]

GCI proved critical and operations at the Anzio-Nettuno Beachhead in support of Operation SHINGLE--an attempt to outflank the German position south of Rome--highlighted the advances made in command and control. At the Anzio-Nettuno Beachhead on 24 February 1944, two SCR-584s (microwave radar) and one SCR-545 (half-long wave, half microwave) arrived to provide initial support to the landing. Eventually, sixteen radar sets arrived to take over from the SCR-268s. The SCR-268 was a great radar, but by 1944 the Germans could effectively jam it.[89] The SCR-584 and SCR-545 played key roles in securing the airspace and thus the beachheads, and continued doing so during the Normandy landings.[90] 39 SCR-584s landed at Normandy on D-Day, providing effective detection and control against German aircraft as it had at Anzio.[91]

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[86] *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, Operations "SHINGLE" Operation Instruction No. 1, Headquarters Mediterranean Allied Tactical Air Force, 19 January 1944," p. 3, Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL.; *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, HQ Northwest African Tactical Air Force Letter to Commanding General, XIII Air Support Command, 30 December 1943, "Operational Directive for Operation "SHINGLE" No. 1," Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[87] *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, "Brief notes on "SHINGLE " Operations and some Lessons Learned," Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[88] *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, Operations "SHINGLE" Operation Instruction No. 1, Headquarters Mediterranean Allied Tactical Air Force, 19 January 1944," p. 3, Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[89] "What Happened at Anzio Beachhead,": 31.

[90] Ibid, 32

[91] "The 584 Earns Its Keep,": 3.

Once ashore, the 64 FW operated in the West, supporting Fifth Army while No 1 MORU operated in the East supporting Eighth Army. Each had a FCC requiring close coordination of the two sectors to prevent fratricide. Both FCC Operations Rooms maintained identical situation maps (air activity picture), told information to each other, maintained connectivity via hard lines, and coordinated their movements. The unit in the most advantageous location controlled the night fighters with GCI.[92]

Operation ANVIL

The growing number of radar sets used during previous operations and the final preparation for Operation ANVIL highlighted the importance of a command and control system. Allied forces began positioning radars for the invasion in the spring so that by early summer 1944 Corsica alone had 30 radars to assist the invasion of France, while Western Italy had 77 British and 46 American stations by July 1944.[93]

Demonstrating the two parts of the command and control system, the 87th FW, under XII TAC, deployed a LW radar set with VHF for forward fighter control linked to the combined Operations Room at BASTI (Corsica). The wing's task was to control tactical fighters via broadcast control to warn allied aircraft of enemy aircraft positions.[94] The 64th FW also under XII TAC, provided close air support for the assault forces from GCI mounted on LSTs and later from the beachhead. The Army forwarded requests for air support via attached air liaisons following the

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[92] *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, "Headquarters Mediterranean Allied Tactical Air Forces, 30 May 1944, "Fighter Control of Organisation of TAF in Italy Immediately before and after the capture of Rome." pp. 2-4, Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL.;

[93] *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, "Mare Nostrum, No. 52, 14 September 1944," p. 32, Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL

[94] *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, "Headquarters Mediterranean Allied Tactical Air Force, 16 April 1944, Outline Air-Plan Operations "BRASSARD," 19 January 1944," p. 3, Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL.

processes already established in earlier campaigns. XII TAC also controlled night fighters with GCI from LSTs, then from ashore. The control of airpower remained centralized with naval aircraft supporting the assault remaining under operational control of XII TAC until the Navy aircraft returned to their ship.[95]

Northern Europe

The command and control system developed, executed, and refined by Ninth Air Force on the continent leaned heavily on and was the culmination of concepts developed during the preceding five years. It is the forerunner of today's system. Specifically, Ninth Air Force patterned itself after Twelfth Air Force in Italy, geared to an Army Group with its ASCs tied to Armies. ASCs became known as Tactical Air Commands (TACs).[96]

By fall 1944, Major General Lewis L. Brereton, commander of Ninth Air Force had three TACs; IX under Major General Elwood "Pete" Quesada with First Army, XIX under Major General O.P. Weyland with Third Army, and XXIX under Brigadier General Richard E. Nugent with Ninth Army.[97] Initially however, IX Fighter Command, responsible for organizing and training the fighter groups, had both IX and XIX Tactical Air Command under it.[98]

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[95] *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, "Outline Air Plan For Operation 'Anvil,'" Headquarters Mediterranean Allied Air Forces, 12 July, 1944, pp. 7-8, 13-14, Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL.; Call # 505.61-1, in the USAF Collection, AFHRA, Maxwell AFB, AL.; *History of Twelfth Air Force, Volume V: The Twelfth Air Force in the Central Italian Campaign*, "Operational Plan "SHINGLE," Headquarters XII Air Support Command, 8 June 1944," p. 2, Call # 650.01-2, in the USAF Collection, AFHRA, Maxwell AFB, AL.
[96] AAFSAT Course Lecture, "Air Ground Coordination or Cooperation System between Air and Ground Forces," February 1944, p. 10, Call # 248.241-16, in the USAF Collection, AFHRA, Maxwell AFB, AL.;
[97] AAFSAT Course Lecture, "Fighter Control and Air Warning in France," 1944-1945, Call # 248.25-11, in the USAF Collection, AFHRA, Maxwell AFB, AL.; *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 281.
[98] *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 271.

In preparation for D-Day, Operation OVERLORD, Headquarters IX Fighter Command established itself at Uxbridge as the control unit of Ninth AF aircraft. IX TAC controlled aircraft first from ships in the English Channel, then on the continent. IX TAC had operational control of IX TAC and XIX TAC aircraft until established on the continent. On 1 August 1944, XIX TAC now established on the continent became operational and IX Fighter Command ceased to exist with all its personnel allocated to IX and XIX TAC. XXIX TAC became operational in Belgium on 3 October 1944. XII TAC transferred from Twelfth Air Force to Ninth AF in October 1944. Finally, First Tactical Air Force activated on 20 October 1944, with XII TAC under it, to plan and execute air cooperation for two Armies under 6th Army Group.[99]

From 15 February to 15 August1944 all allied tactical air operations including heavy bombers allocated were under operational control, centrally planned, and directed by HQ, Allied Expeditionary Air Forces (AEAF). AEAF was also responsible for planning the integration of ground and naval forces. In preparation for D-Day, HQ AEAF established an advanced headquarters at Uxbridge with elements of the Ninth AF and 2 TAF, and provided the control elements for ground forces going ashore. In August 1944, AEAF Advanced HQ moved to the continent and consolidated with AEAF (Main), finally becoming the Air Staff, SHAEF on 15 October 1944. While the AEAF was responsible for the overall planning and coordinating as the senior command element, the Tactical Air Commands, to include the British 2 TAF "were the key tactical units coordinating the planning requirements and execution of the operations."[100]

AF headquarters coordinated TAC movements and conducted planning with ground forces for large-scale operations or medium

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[99] Ibid, 276, 281-282.
[100] Ibid, 267-268, 271, 339.

bomber operations, but the TACS planned day-to-day air operations.[101] The TACs controlled airpower and air operations maintaining operational control while the Wings were responsible for administrative functions and training. Wing HQs issued orders from the TACS to the Groups and they in turn assigned missions to the various Squadrons.

The TACs adjusted to meet the needs and circumstances of their organizations. Despite minor differences, they generally operated utilizing the same tactics, techniques, and procedures. First, the Commanding Generals of the TACs found it best to be close to the Army Commander, although they could be located anywhere. During rapid Army advances, the TACs created a forward Headquarters, called TAC (Advanced) or "X-Ray," that moved up with the ground forces. The advanced headquarters included the Commanding General, aides, the Combat Operations Section, with the Tactical Control Center added as necessary, and a small Signals detachment. TAC (Main or Rear) handled administrative functions. A single landline and an FM radio with W/T connected TAC Main and Advanced. Once the advance slowed, the headquarters rejoined and signal units added new lines to all the units and new airfields in the TAC.[102]

The Combat Operations Section, sometimes called the Combined Operations Center, was comprised of both air and ground personnel; A-2 and A-3 personnel, G-2 and G-3 (Air). This group required close relationships to be effective. Within the Combat Operations Section, the A-3 developed long-range plans while the Combat Operations Officer

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[101] Ibid, 340-341.

[102] Report, "Tactical Air Operations in Europe: A Report on Employment of Fighter-Bomber, Reconnaissance and Night Fighter Aircraft by XIX Tactical Air Command, Ninth Air Force, in Connection with the Third US Army Campaign from 1 August 1944 to VE Day,, 9 May 1945," Headquarters (Advanced) XIX Tactical Air Command, 19 May 1945, pp. 1, 16-17, Call # 168.., in the USAF Collection, AFHRA, Maxwell AFB, AL; *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 282-3, 340-341.; AAFSAT Course Lecture, "Mission Control and Liaison," June 1945, p. 1, Call # 248.241-3, in the USAF Collection, AFHRA, Maxwell AFB.

translated these plans into daily action and ran daily operations. The Combat Operations Officer worked with the G-3 (Air) to determine "the current bomb line, selection of special targets, preparation of reconnaissance plans and the appropriate allocation of the available forces." Finally, the Combat Operations Section developed all Standard Operating Procedures and transmitted all data across the command.[103]

Conversely, air representatives operated from Ground Forces HQ, while controllers collocated with Corps, Division, and Combat Command headquarters. The processes established earlier in the war remained unchanged. The Army Group and Army HQ conducted a briefing every morning with air and ground commanders, both staffs, and other air representatives. The G-3 provided ground updates on the prior day's operations, current plans, and next day's plans while the G-2 provided current intelligence. The A-2 (TAC) provided the previous day's result and updates to enemy activity, the A-3 (TAC) provided a current operations update, and the G-1 a personnel and a prisoner of war update. After this meeting, the Army Commanding General met with his Corps and Divisions Commanders and the TAC Commanding General.[104]

The TACs planned day-to-day operations at the 1930 evening brief, call the "Evening Target Conference" at the Combined Operations Center, TAC HQ. The G-2 (Air) provided a current operations update and intelligence information while the G-3 (Air) provided the plan for next day and the ground force air requests. The A-2 delivered an intelligence update and the A-2 target officer presented a list of potential targets. Finally, the weather officer gave his forecast. After the brief, the Combat

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103 AAFSAT Course Lecture, "Mission Control and Liaison," June 1945, p. 1, Call # 248.241-3, in the USAF Collection, AFHRA, Maxwell AFB.; & *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 283, 340, 370.; AAFSAT Course Lecture, "Mission Control and Liaison," June 1945, p. 1, Call # 248.241-3, in the USAF Collection, AFHRA, Maxwell AFB.

104 *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 286, 340, 343.

Operations Officer announced the forces available after assigning aircraft per the priority. Extra aircraft went into a pool for on call requests that came from the Corps or Divisions, although these were few. Generally, aircraft needed for on call requests came from armed reconnaissance sorties. The G-3 (Air) made any final adjustments before transmitting the orders to wing headquarters. The Combat Operations Section transmitted orders to Groups assigned under TAC Headquarters. The Control Groups used these orders to create its control plan and the flying units planned their tactical execution.[105]

Air planners considered all ground force requests and the overall air plan, allocating aircraft according to the following priority: 1) air superiority, 2) special targets, bomber escort, 3) armed recce to interdict troops and supply movements, and 4) armored column support. Armored column support consumed 30-60% of available TAC sorties and only pinned down infantry received air support.[106]

For preplanned missions, the TACs forwarded drafted ground support plans to TAF for approval. Air force representatives from various commands at TAF worked out the details and created alternate plans. Large Army assaults required joint planning. Planners matched aircraft and weapons to targets, planned reconnaissance missions, and designated on call aircraft. A completed and approved TAF plan went to the units. During stable operations, armed reconnaissance and escort provided the most flexibility. Any special target requests had to support the ground scheme of maneuver.[107]

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[105] AAFSAT Course Lecture, "Mission Control and Liaison," June 1945, p. 1, Call # 248.241-3, in the USAF Collection, AFHRA, Maxwell AFB.; *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 343-344.
[106] *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 342-343.
[107] Ibid, 341, 343.

Immediate or on the spot requests came via message to the Combat Operations Officer or Chief Controller and took priority over a preplanned mission. This request required diverting aircraft from pre-planned missions to the new target. The Army G-3 (Air) evaluated the request against the Army plan and plotted the mission against the bomb line. If approved by the Army G-3 (Air), the A-3 combat operations officer evaluated the request and if approved, forwarded it to Headquarters, Group, and Squadrons for execution. The Combat Operations Officer notified the requesting unit over the air request network of the approval with the number of aircraft and time over target, or a refusal.[108]

The A-2 Target Section derived targets from multiple sources such as from ground forces and reconnaissance units. The target committee comprised of Combat Ops, G-3 (Air), Operational Research Section, and G-3 Target Officer reviewed the targets and presented them at the evening meeting to the combat operations officer for an allocation decision. A tactical boundary separated tactical (ground forces) and strategic (air forces) areas. Targets located within each area attacked by the other required coordination. [109]

If a dynamic target emerged, the controller notified the Chief Controller at Combat Ops and aircraft immediately diverted to the higher priority task. If a reconnaissance aircraft spotted the target, it rendezvoused with the fighter and talked the fighter onto the target. Additionally, an L-5 aircraft with the SCR-522 radio set helped escort the fighter-bombers to the target. This aircraft, called a "Horsefly," kept contact with the corps and divisions through the Air Support Party Officers (ASPO) or Tactical Air Party Officer (TAPO). If "Horsefly" saw a

[108] Ibid, 342-343.
[109] Ibid, 339, 344.

target, they contacted the ASPO and then controlled the fighter to the target. These actions helped quicken the reaction cycle.[110]

ASPOs were qualified pilots attached to Corps, Division, or Combat Command HQ as liaison officers "to advise and assist the commander on all matters that affect the command." They evaluated targets selected by G-3 (Air), and eventually controlled visual strikes from the ground and with armored divisions. Ground Liaison Officers (GLO) were ASPO counterparts attached to each HQ down to group level and tactical and photo reconnaissance squadron and night intruder and night photo squadron. They briefed pilots, passed information to the G-3 (Air), and monitored the Intelligence Broadcast network.[111]

Finally, the Army G-3 and G-3 (Air) proposed the bomb-line based on army inputs. The bomb-line, normally placed 5-35 miles in front of troops during fast movements and at 500 yards during static operations for fighters or 1000 if medium bombers used. The MEW or SCR 584 radar controller, through a "Horsefly" or visual by the ASPO handled an attack within the bomb line.[112]

Communications

The TACs used four communication networks: 1) The Command Net for Command-Wing-Group and lateral unit connectivity, 2) Control Net for TCC, FDP, Intel LWR, Ground Observers, and lateral units, 3) Liaison Net for command Tactical Air Parties at the Corps, Divisions, and Combat Command, and 4) an Air-Ground Net for aircraft and ground

[110] Report, "Tactical Air Operations in Europe: A Report on Employment of Fighter-Bomber, Reconnaissance and Night Fighter Aircraft by XIX Tactical Air Command, Ninth Air Force, in Connection with the Third US Army Campaign from 1 August 1944 to VE Day,, 9 May 1945," Headquarters (Advanced) XIX Tactical Air Command, 19 May 1945, pp. 1, 16-17, Call # 168.607-36, in the USAF Collection, AFHRA, Maxwell AFB, AL.; *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 373.
[111] *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 286.
[112] Ibid, 355.

stations at airfields, control points, and Tactical Air Parties. These networks, used landline and FM radio-telephone and teletype, HF W/T radios, car and air couriers, and VHF R/T radio.[113]

All communications equipment for Advanced Ninth Air Force HQ was mobilized on K-53 vans and K-52 trailers and included landlines, radio, crypto, teletype switchboards, and repair facilities. Duplicate sets enabled air and ground forces to leap frog as movement progress.[114]

Technology

Entrance into the war accelerated radar development. The need for specific radars to handle the expected mobile nature of combat operations across the globe led to a focus on mobile and lightweight radars, although not at the expense of highly accurate and long-range systems. Despite setbacks due to technological constraints and production capabilities, American radar technology was quickly developed and adapted to meet military needs with a wide variety of capable systems.

Radar

By 1942, the demand for mobile radars grew as it became evident American forces would need to assault beaches and that maneuver warfare was the wave of the future. The SCR-270 and SCR-268, though mobile, still required heavy trucks to transport.[115] This requirement drove the need for lightweight sets that "could be packaged for hand-carrying by a small number of men, loaded with the first waves of an assault, and assembled quickly for operations whether in the early stages

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[113] Report, "Tactical Air Operations in Europe: A Report on Employment of Fighter-Bomber, Reconnaissance and Night Fighter Aircraft by XIX Tactical Air Command, Ninth Air Force, in Connection with the Third US Army Campaign from 1 August 1944 to VE Day,, 9 May 1945," Headquarters (Advanced) XIX Tactical Air Command, 19 May 1945, pp. 1, 16-17, Call # 168.607-36, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[114] *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 360.

[115] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 263.

of an assault or in moving through the jungle."[116] The Fighter Command School at AAFSAT became responsible for designing the system, researching the radios, improvising lightweight radars and determining the organizational structure of the units.[117] The SCR-602-T-8 or AN/APS-3, a Lightweight Warning Radar, copied from a British set the US called SCR-602-T6, was an outgrowth of this specific need.[118]

Although the SCR-602 did well in North Africa and in the Pacific, a lighter and better radar family followed--the AN/TPS (Army Navy/Transportable Radar Search) -1, -2, and -3. All three designs emphasized lightness and portability for initial assaults, and quick assembly. As a result, they were not as durable or effective as larger fixed radars, but nonetheless served their intended purposes. The TPS-1 weighed 2,300 pounds, had a 70-mile range, a 5" PPI, and was more jam resistant due to its high frequency. Its 19 boxes fit in a single truck and required a four-man team to operate. The TPS-2 was the least capable and durable, but weighed only 700 pounds and could be carried by eight men. It had a 60 mile range, no IFF, no PPI, no autorotation, was up and running in 20 minutes and required only two operators. The TPS-3 weighed 1600 pounds, had a 100-mile range, a 5" PPI, and required only four men to operate.[119]

While the SCR-268 played the leading role in getting the American radar development effort off the ground and proved one of the most capable fire control radar sets of the early war period, like all technology it was destined to be replaced. In February 1944, the SCR-584 became the standard fire control radar with the ability to provide accurate fighter

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[116] Ibid, 263.

[117] *Army Air Force Historical Studies No 13, The Development of Tactical Doctrine at AAFSAT and AAFTAC,* 40-41.

[118] H. M. Davis, First Lieutenant, *History of the Signal Corps Development of U.S. Army Radar Equipment, Part I: Early Research and Development – 1918-1937* (Historical Section Field Office, Office of the Signal Corps Officer, Army Service Forces, 27 March 1943), 31.; Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 261-63.

[119] "Portable Radar Gets Better," *Radar*, no. 3 (30 June 1944): 22-23.; "Task Force Radar," *Radar*, no. 6 (15 November 1944): 38.

control. It was a mobile (1 van) microwave radar set, requiring a chief, a PPI operator, a range operator, and a maintenance technician to operate.[120] The SCR-584 became an integral and important part of the fighter control system due to its mobility and accuracy (25 yards in range, 1 mile in azimuth). It was so effective, much as the MEW, that it was used to intercept V-1 flying bombs.[121]

The Army's road to radar did not follow a smooth and straight path. It overcame several problems and capitalized on several unintended benefits. The first problems were technological. At the time, early warning radars, like the British Chain Home radars, required separate receivers and transmitters to allow for the detection of aircraft. One of the most important innovations was the use of the spark gap principle. The use of the "spark-gap principle to the joint switching mechanism for the first time made it possible to switch the power from the transmitter and receiver and back again."[122] This alleviated the need to have two locations for the receiver and transmitter and allowed for a more compact design, thus enhancing mobility, set-up, and maintenance.

Second, all radars were initially built to operate on a single frequency, but the United States quickly began looking for sets with different operating frequencies to counter jamming. The United States began seeing jamming on the battlefield and wanted to minimize its impact in the future.[123] This led to more complicated radar designs and therefore more complex engineering problems.

Third, disputes over equipment existed between the Army branches. For example, a problem arose over the allocation of the SCR-

[120] "Fighter Bomber Control: A Compilation of Procedures Used by the Ninth Air Force During Operations on the European Continent," pp. 10-11, Call # 168.601-34, in the USAF Collection, AFHRA, Maxwell AFB AL.; "What Happened at Anzio Beachhead," *Radar*, no. 4 (20 August 1944): 31.
[121] "The 584 Earns Its Keep," *Radar*, no. 5 (30 September 1944): 2.; "Fighter Bomber Control: A Compilation of Procedures Used by the Ninth Air Force During Operations on the European Continent," pp. 10-11, Call # 168.601-34, in the USAF Collection, AFHRA, Maxwell AFB AL.
[122] Dulany Terrett et al., *The Signal Corps: The Emergency (to December 1941),* 125.
[123] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 263.

268 in the face of limited production. Although the Air Corps initially did not request the SCR-268, delays in SCR-270 and SCR-271 production pushed the Air Corps to request the SCR-268 while awaiting the SCR270s, but there were not enough SCR-268s to meet all needs. The Air Corps was denied the SCR-268s due to its limited coverage for the early warning role and its better role as a gun laying radar set.[124] There was also a dispute regarding the quality of American versus British equipment. The Air Corps had the general impression that British equipment was better, while the Signal Corps insisted its equipment was as good or better.[125]

Finally, the depression had a heavy impact on the Signal Corps' budget.[126] Important decisions on what to fund based on existing requirements drove what resources would be available and distributed between the services as the United States prepared for war.

Despite these technological, developmental, and resource problems, by the end of the war, the United States had a wide range of effective radars serving in a variety of roles. They included gun-laying radars like the SCR-268 and SCR-584, various early warning air defense radars, the SCR-270 and 271, and the GCI radars SCR-516, 527, and 588. The SCR-516 was a modified SCR-268, the SCR-527 an American copy of British GCI and the SCR-588 a Canadian built CHL/GCI combo. SCR-527 development followed the SCR-588.[127]

By end of war, radar became indispensible and necessary to enable worldwide employment of the Air Force. General Arnold stated,

> Radar is an outstanding contribution to the effectiveness of an air force. It is a device which enormously extends the range, power, capabilities and accuracy of human vision. Radar is a primary facility in an all-weather, 24-

[124] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 255.
[125] Ibid, 199-200.
[126] Ibid, 67.
[127] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 256.

hour air force for bombing, gunfire, navigation, landing and control. The structure of the air force, the planning of its operations, its training program and its organization must take radar into account." It is a "potent weapon which has done so much to increase our effectiveness on all fronts.[128]

Ground Control Intercept

Once the Air Corps became aware of GCI in late 1940, it quickly climbed to the top of the priority list for General Chaney at Air Defense Command, despite its still being in the experimental stages in Britain.[129] The Air Corps attempted to modify the SCR-270 to give it similar capabilities as GCI, leading to the SCR-516 in 1941.[130] Once the first British GCI set arrived in October 1941, tests against the SCR-268 found it to be less accurate. Portions of the British GCI set were better, such as how it supplied targeting data, but the Americans still favored their design. Nonetheless, the SCR-527, the American copy of the British GCI, arrived in 1943.[131] In 1942, the Signal Corps Radar Laboratories also began converting SCR-268s to GCI sets by adding a PPI cathorade-tube, more antennas, multiple frequencies, and target height information because the SCR-268 had only approximate height finding capability. In May 1942, the SCR-615, a GCI microwave radar was tested. This set used microwaves versus the long waves used in the SCR-527 and SCR-588. It had 10cm microwaves with a range of only 90 miles, but it tracked low level targets better than long-wave sets.[132] This broke the

[128] H. H. Arnold, *Second Report of the Commanding General of the Army Air Forces to the Secretary of War: 27 February 1945* (Washington D.C.:, 1945), 76; H. H. Arnold, *Third Report of the Commanding General of the Army Air Forces to the Secretary of War: 12 November 1945* (Washington D.C.:, 1945), 63, 69.
[129] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 248.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 118.
[130] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 256.
[131] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 118.; Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 96.; Terrett etal., *The Signal Corps: The Emergency (to December 1941)*, 267-68.
[132] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 32, 99, 260-61.

British paradigm of regarding long-wave sets as the best radars. These technological exchanges also enhanced each country's scientific knowledge and surely spurred a competition that led to better radar designs.

The SCR-584 (Close Control Unit) became the most famous and capable American GCI radar used by the TACs. Originally designed for AAA tracking, it evolved into a blind bombing radar, and finally a close control radar.[133] The SCR-584, a10 cm radar was a highly accurate and mobile radar with 25-30 miles range. Its very narrow (4 degree conical) beam made it difficult to jam and provided greater accuracy. It could detect enemy vehicle movement and artillery positions and control aircraft for blind bombing during bad weather. To do this the radar tracked the aircraft flying at a specific speed and altitude. A Norden Bombsight mounted next to the plotting table determined the release time and point. The pilot released the bombs based on a controller's countdown reaching "zero." The same capability made it ideal for controlling Pathfinder missions at night, guard photo planes, and assist with navigation and night bombing. Finally, it made it possible for controllers to accurately guide and talk an aircraft directly to a target. Weather was no longer a factor as aircraft could now fly under a solid undercast, a capability effectively employed during the fall/winter 1944/1945.[134]

Microwave Early Warning

The Microwave Early Warning Radar, commonly referred to as the MEW and officially as the AN/CPS-1 (C = air transportable), was one of

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[133] "Fighter Bomber Control: A Compilation of Procedures Used by the Ninth Air Force During Operations on the European Continent," p. 20, Call # 168.601-34, in the USAF Collection, AFHRA, Maxwell AFB AL.; *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 372.

[134] "Fighter Bomber Control: A Compilation of Procedures Used by the Ninth Air Force During Operations on the European Continent," pp. 20-21, Call # 168.601-34, in the USAF Collection, AFHRA, Maxwell AFB AL.

the most remarkable technological developments of the war. It provided an unprecedented capability in terms of range and number of aircraft it could track and played a large role in allied operations during the war's final year. The MEW transformed American fighter control from purely defensive to a combination of offensive and defensive control.

MEW development began in early 1942 from military and industrial work on the SCR-615, but it was not used in combat until 1944.[135] Initial testing showed the potential for target detection out to 177 miles for a 16,500 ft target, and a 400-mile radius for higher altitude targets. However, 200 miles for a 30,000 ft target became the standard for planning purposes.[136] The MEW was capable of tracking a large number of targets, had excellent horizontal resolution, had five 30cm offsetting PPI oscilloscopes to see active areas in more detail, used a 23kW engine for power generation, was manned by 30-50 personnel, and required eight trucks to carry its 66 tons. Initially designed as an early warning radar, in time the MEW functioned as a means of fighter control. A glass board in the Fighter Control Center contained the mirrored image of the information on the MEW's PPI. Commanders used this information to maintain situational awareness.[137]

The MEW provided the ability to conduct scope control for six controllers, with 15-second updates providing the controller data on where the fighter is and not where it was. It also eliminated the need to

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[135] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 274-76.; Robert Buderi, *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution*, Sloan Technology Series (New York: Simon & Schuster, 1996), 136.

[136] "Fighter Bomber Control: A Compilation of Procedures Used by the Ninth Air Force During Operations on the European Continent," pp. 9, 12. Call # 168.601-34, in the USAF Collection, AFHRA, Maxwell AFB AL.; *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 370.

[137] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 196, 391.and Buderi, *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution*, 136.; Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 274-76.; AAFSAT Course Lecture, "Fighter Control and Air Warning in France," 1944-1945, Call # 248.25-11, in the USAF Collection, AFHRA, Maxwell AFB, AL.

filter. It not only provided a long-range capability, it also offered accurate target discrimination within 300 yards in range and 8/10 of 1 degree in azimuth.[138] Adding a B-Scan Scope allowed the MEW to conduct the reporting and controlling functions simultaneously.[139] Half the scopes in the MEW were B-Scan scopes so controllers could watch aircraft in a sector.[140]

The MEW consisted of two radar units operating on a single frame. One operated on a high and another at a low angle, sharing a common power supply. It was an extremely capable radar, used to control aircraft and track the V-1. It used microwaves and possessed extremely sensitive antennas, but lacked height capability.[141] The British-designed Type 24 height finder radar eliminated this deficiency, allowing the MEW to be used for fighter control.[142]

Despite the MEW's massive size, it became a mobile radar. It could be broken down in one and one-half days, set up in the same time, and transported in 10 trucks, while the VHF equipment required six more trucks. It had the ability to operate 21 hours a day, the other three required for maintenance. To make the MEW mobile required some modifications, made over 11 days in April 1944 in preparation for D-Day. The mobile MEW used the British Type 13 height finder instead of the British Type 24.[143]

The MEW and its associated AMES Type 13 height finders usually were located 20-40 kilometers from the front lines. The MEW could handle four squadrons, one from each of the two Forward Director Posts,

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[138] AAFSAT Course Lecture, "Fighter Control and Air Warning in France," 1944-1945, p. 7, Call # 248.25-11, in the USAF Collection, AFHRA, Maxwell AFB, AL.
[139] Ibid, 8.
[140] *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 370-372.
[141] "Sixty-Six Tons of MEW," *Radar*, no. 3 (30 June 1944): 5.
[142] "In This Issue," *Radar*, no. 4 (20 August 1944): 2.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 196.
[143] "The Mobile MEW," *Radar*, no. 5 (30 September 1944): 31-32.

and one from each of the three SCR-584s. A standard communications network (radio, telephone, teletype and encryption equipment) tied this system together. The Forward Director Posts had 2-3 British Type 11, 13, 15, or 22 radars. The Type 11 was a medium wave, very mobile (3 vans), good low coverage radar, but provided no height capability. It had a one-degree in azimuth and .5 mile accuracy with a range of 80 miles for a 20,000 ft target. The Type 13, a mobile (3 vans) microwave radar had with accuracy to 1 mile in range, 1,000 ft in height, and an 80 mile range. The Type 15 medium mobile radar (5 vans) had bad low-level coverage but height information on 20,000 ft targets at 80 miles. The Type 13 supplemented the Type 11 and 15 to provide good height, while the Type 22 was a Type 13 and 11 combination set.[144] Light Warning Radars, the British Type 6 MkIII and AN/TPS-3 served as gap fillers.[145] Thirty ground observers divided into five sections provided additional coverage and completed the system.[146]

Few MEW radar sets were built, all by hand, with the first delivered in January 1944. By June 1944, five MEWs were in existence; two in England, one converted to a mobile MEW for use on the continent, one in the Mediterranean, and one getting ready for deployment to the Pacific.[147] Despite these limited numbers, the MEW provided tremendous capability and was a technological marvel for its time.

The MEW used during D-Day was assembled in England on 28 January 1944. It took from January to June 1944 to set up, train the

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[144] "Fighter Bomber Control: A Compilation of Procedures Used by the Ninth Air Force During Operations on the European Continent," p. 10, Call # 168.601-34, in the USAF Collection, AFHRA, Maxwell AFB AL.; "Radar at the Front," 11-12.; Freienmuth, "What did the WWII Signal Aircraft Warning Battalions in the ETO do?"
[145] Brown, A Radar History of World War II: Technical and Military Imperatives, 399-400.; "Radar at the Front," 12.
[146] Brown, A Radar History of World War II: Technical and Military Imperatives, 399-400.; AAFSAT Course Lecture, "Fighter Control and Air Warning in France," 1944-1945, Call # 248.25-11, in the USAF Collection, AFHRA, Maxwell AFB, AL.; Freienmuth, "What did the WWII Signal Aircraft Warning Battalions in the ETO do?"
[147] "Sixty-Six Tons of MEW," 4.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 196.

personnel, and work out the bugs. On D-Day, the MEW was absent from the beaches, but not the theater. A MEW placed at Hastings, at the entrance of the Straits of Dover on the English coast facing Le Havre, Cherbourg, and the Normandy coast provided critical control to invasion forces. It had many PPI and B-Scopes to handle the large amounts of air traffic, coupled with the VHF D/F equipment to keep track of allied aircraft and then plotted on a status board.[148] The VHF D/F equipment provided range out to 100 miles, and worked well supplementing the radar picture.[149]

During D-Day operations, the MEW provided big picture data for all the air traffic in the English Channel. Air control operations over Normandy used British Air Ministry Experimental Station (AMES) Type 11 radars, operated by British controllers on ships, although too much air traffic, IFF problems, ground, water, and ship clutter were impediments to effective control.[150] Soon after the initial landings at Normandy, British and American radar followed amid falling mortar rounds and machine gun fire. These radars included the British Light Weight Radar, SCR-602, SCR-268, and the SCR-584 (gun laying microwave). During the landing, some radar sets capsized, but good invasion preparation resulted in watertight containers. Opened and erected, they immediately began operations the next morning (D+1), providing fighter control.[151] Although the MEW landed on D+6 and took until D+10 to conduct operations on the continent, its assistance during

[148] "Sixty-Six Tons of MEW," 3.; Buderi, The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution, 219
[149] "In This Issue," 2.; AAFSAT Course Lecture, "Fighter Control and Air Warning in France," 1944-1945, Call # 248.25-11, in the USAF Collection, AFHRA, Maxwell AFB, AL.
[150] Brown, A Radar History of World War II: Technical and Military Imperatives, 391.
[151] George Raynor Thompson and Dixie R. Harris, The Signal Corps: The Outcome (Mid- 1943 through 1945) (Washington,: Office of the Chief of Military History U.S. Army; for sale by the Superintendent of Documents U.S. Govt. Print. Off., 1966), 102-03.; Brown, A Radar History of World War II: Technical and Military Imperatives, 391.

the initial landings proved instrumental in the landings' success.[152] Its primary task was to control day and night fighters against the anticipated large numbers of German aircraft that never appeared.[153] However, the air picture provided improved situational awareness that improved the general's decision-making.

In the first month, the MEW conducted over 2000 intercepts, and gave fighters the situational awareness to enable them to focus on ground attack.[154] Dr. John G. Trump, Director of the British Branch Radiation Laboratory, was possibly guilty of understatement when he said, "Perhaps the outstanding operational development was the employment of the MEW by the tactical air commands for the accurate navigation control of all types of fighters, photoreconnaissance, night fighter, and intruder operations."[155]

By early September 1944, the major problem confronting fighter control units in XIX TAC was keeping up with the pace of Third Army. An unwieldy fighter control structure had to adjust. Before September 1944, fighter control units were assigned to one of the wings in XIX TAC that was always located near their airfield. Third Army's rapid movement created a situation where the Third Army was at St. Dizier and the fighter control units at Le Mans, almost 220 miles away. Patton's Army was effectively without fighter control, and more importantly without air defense warning. Placing the fighter control units directly under TAC versus under a Wing resolved this problem by giving it the flexibility to follow Third Army. XIX TAC had also experienced the same problems and followed suit with the same solution.[156] Placing the fighter control units

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[152] Thompson and Harris, The Signal Corps: The Outcome (Mid-1943 through 1945), 102- 03.; Brown, A Radar History of World War II: Technical and Military Imperatives, 391.
[153] "The Mobile MEW," 31.
[154] "What Happened in the Breakthrough," Radar, no. 8 (20 February 1945): 5.; "The Mobile MEW," 33.
[155] "Radar and the War in Europe," Radar, no. 10 (30 June 1945): 45.
[156] "Radar and the War in Europe," 45.; AAFSAT Course Lecture, "Fighter Control and Air Warning in France," 1944-1945, Call # 248.25-11, in the USAF Collection, AFHRA, Maxwell AFB, AL.

with TAC headquarters and thus collocated with Army headquarters, situated the control units near the front lines, thus ensuring adequate radar coverage and improving performance.[157]

Adaptation occurred not only with the organizational structure, but also with employment methods. Initially, the MEW's primary function was to control night fighters (since the Luftwaffe as a rule appeared only at night by that point in the war), and to report aircraft activity to the Forward Director Post and the Forward Control Center. Used mainly for surveillance, the MEW could also control aircraft. This was not normal operating procedure, as tactics and techniques were developed before the MEW's deployment. At times, the MEW took control because it could leverage getting terrific data directly to controllers on scope without filtering. It also received data from its ground observers throughout the area.[158]

Eventually, its accuracy led to the MEW becoming a primary control platform to vector a fighter directly onto an enemy aircraft, rather than perform only as a surveillance platform.[159] It controlled long-range P-51s on bomber escort missions, Eighth AF bombers, and tactical aircraft such as the P-47. The MEW's long-range and accuracy allowed controllers to control aircraft across a wide front and counter most Luftwaffe actions before they could affect allied activity.[160] By the end of

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157 "Radar and the War in Europe," 45.
158 "The Mobile MEW," 33.
159 Ibid, 33.
160 "Combined Operational Planning Committee. Fourteenth Periodic Report of Enemy Daylight Fighter Defenses and Interception Tactics. Period 3 February, 1945 – 28 February 1945," Report dated 14 February 1945. Call # 168.7020-29, in the USAF Collection, AFHRA, Maxwell AFB, AL.; "Combined Operational Planning Committee. Thirteenth Periodic Report of Enemy Daylight Fighter Defenses and Interception Tactics. Period 17 December, 1944 – 2 February 1945," Report dated 23 December 1944. Call # 168.7020-29, in the USAF Collection, AFHRA, Maxwell AFB, AL.; *The Effectiveness of Third Phase Tactical Air Operations in the European Theater, 8 May 1944 – 8 May 1945* (Prepared by the Army Air Forces Evaluation Board in the European Theater of Operations, August 1945), 293.

1944, the MEW controlled all fighters escorting bombers.[161] In fact, the MEW was so effective at fighter control that General Patton became upset when higher headquarters diverted the MEW to track V-1s.[162]

The MEW's increased capability allowed the fighter control units to take additional missions such as the control of P-61 night fighters over Third Army and tracking night photo-reconnaissance planes over enemy territory. Before this, the photo planes, using the British GEE navigation system, were too far away from the GEE transmitters and could not pinpoint their location to get their pictures. With control from the MEW, they could now accomplish their mission.[163]

Identification Friend or Foe

In many ways, America's IFF system was superior to its British counterpart. The British system relied on DF equipment to get an aircraft position and correlate that code to a known radar position. This took time, but did show up as an intensified reflection on the oscilloscope.[164] Allied interoperability issues resulted in the adoption of a less advanced technology. The United States and Britain chose the new British Mark II to minimize the identification problem and maximize coalition efforts for BOLERO, the code name for concentrating American forces in Britain for an assault across the English Channel, creating the first universal allied IFF.[165] The United States copied the British Mark II IFF and called it the SCR-535, tuning it to the same frequency as the SCR-268 and SCR-270

[161] "Combined Operational Planning Committee. Fourteenth Periodic Report of Enemy Daylight Fighter Defenses and Interception Tactics. Period 3 February, 1945 – 28 February 1945," Report dated 22 February 1945. Call # 168.7020-29, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[162] Buderi, The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution, 225.

[163] AAFSAT Course Lecture, "Fighter Control and Aircraft Warning in the European Theater of Operations," 1944-1945, Call # 248.25-23, in the USAF Collection, AFHRA, Maxwell AFB, AL.

[164] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 197.

[165] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 242.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 264-65.

radar sets.[166] They used the Mark II until 1943 when the Mark III replaced it and became the new allied standard IFF.[167]

The Mark III's major improvement over the Mark I and Mark II was that it had a wide band of frequencies and automatic gain stabilization, eliminating the need for in-flight adjustments to maintain the correct frequency. It was still vulnerable to enemy interrogation.[168] Despite America's IFF technological superiority in the Mark IV over the Mark III, the allies never used the Mark IV during the war and kept it as a backup in case the Mark III fell into German possession. The SCR-515, airborne IFF component, SCR-532, short-range IFF ground component, and SCR-533, long-range IFF ground component comprised the American Mark IV IFF.[169] The SCR-695 IFF airborne and SCR-729 served as air-to-air interrogators, providing the capability for an aircraft to interrogate another aircraft in the air to determine friend or foe, a feature extremely helpful at night.[170]

The United States did not immediately exploit IFF's full potential despite the tremendous capability it brought to fighter control. Many aircrews had a difficult time understanding and accepting IFF's importance and the benefits IFF brought to the controller and to the overall battle picture. A pilot only had to turn it on, but if he did not, it caused problems.[171] Misuse or non-use of IFF led to some instances of fratricide.[172] In May 1944, a joint Army-Navy team investigated IFF use and found that only 75% of aircraft were using IFF at one airbase. A

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[166] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 85, 242.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 131-32.; "IFF: It's Not Doing Its Job," *Radar*, no. 2 (May 1944): 22.
[167] Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 266.
[168] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 131.; "IFF: It's Not Doing Its Job," 22-23.
[169] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 131.; Terrett et al., *The Signal Corps: The Emergency (to December 1941)*, 243, 264.
[170] "IFF: It's Not Doing Its Job," 22.
[171] "IFF: It's Not Doing Its Job," 22.
[172] Ibid, 21.

week of instruction brought usage to 90%, and further training up to 97%, still not exploiting IFF to its full potential. Aircrew acceptance and lack of procedures to turn on the IFF were deemed the problems, not the equipment.[173] By February 1945, IFF was still in limited use, since identification continued by voice communications and VHF-DF equipment.[174]

Air Interception Radar

As late as 1944, radar equipment was still not sufficiently accurate to place a friendly fighter in the exact location behind an enemy aircraft to facilitate a shoot down. GCI could normally place the friendly fighter one to one-half miles behind a target.[175] AI equipment on the fighter assisted with the interception and increased the success rate. After GCI placed the aircraft within a range to acquire the enemy target on the AI scope, the fighter pilot took over the final steps of the interception using his onboard AI set.

When the Air Corps finally received the SCR-520 in 1942, it provided the operators with target range (in nautical miles), azimuth, and elevation (in degrees) on two oscilloscopes. The pilot's oscilloscope ("C" scope) provided the bearing to the target while the operator's oscilloscope ("B" scope) provided range and bearing. A range meter controlled by the radio operator was available to the pilot for use during the intercept. The "B" scope's horizontal axis showed antenna azimuth bearing in degrees and its vertical axis showed range to the target in ranges of up to 1, 10, and 100 miles. The "C" scope's horizontal axis was the same as the "B" scope's, but its vertical axis showed the vertical azimuth to the target.

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173 "How's Your IFF?," *Radar*, no. 5 (30 September 1944): 30.
174 "Radar at the Front," *Radar*, no. 8 (20 February 1945): 13.
175 AAFSAT Course Lecture, "GCI- AI Team," January 1944, Call # 248.25-8, in the USAF Collection, AFHRA, Maxwell AFB AL.

The antenna was an internal rotating parabolic antenna located in the aircraft's nose.[176]

The SCR-520 was a very large AI set, requiring two operators. The sets went into the A-20Gs. The SCR-720 was a reduced size, S-band set, and later installed in the P-61. It had the ability to see 90 degrees laterally, 10 degrees below, 50 degrees above, and out to 10 miles,[177] although it lacked directional accuracy, preventing blind firing. This was a limited problem, as Allied IFF procedures required visual identification.[178] The SCR-720's major advantage was the elimination of the ground return problems in early AI sets.[179] By 1944, after running through a number of various variants, the Mark X, a modified SCR-720 became the British standard.[180]

There were several initial problems with the new AI equipment. There were not enough skilled operators to direct pilots to within visual range of a target at night and ground controllers were incapable of bringing the fighter to a position for visual acquisition either through radar or through D/F equipment. Initially Chain Home radar had too great of an error rate in radar azimuth and height data, but this was solved with the development of newer Chain Home B mobile radars that gave altitude data to within 1000ft at 50 miles.[181] The development of a PPI allowed the position of at least two aircraft to be displayed on a single

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[176] AAFSAT Course Lecture, "GCI- AI Team," January 1944, Call # 248.25-8, in the USAF Collection, AFHRA, Maxwell AFB AL.
[177] "The Nightfighters," *Radar*, no. 8 (20 February 1945): 45.; Report, "History & Background of Night Interception," 1940, Call # 248.252-24, in the USAF Collection, AFHRA, Maxwell AFB, AL.
[178] "The Nightfighters," 44.
[179] Thompson, *The Signal Corps: The Test (December 1941 to July 1943)*, 377.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 117.
[180] "The Nightfighters," 49.
[181] AAFSAT Course Lecture, "GCI- AI Team," January 1944, Call # 248.25-8, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report, "History & Background of Night Interception," 1940, Call # 248.252-24, in the USAF Collection, AFHRA, Maxwell AFB, AL.

scope. This combined with trained AI operators created a deadly combination.[182]

Other Equipment

Operational necessity and success of the ground forces forced the command and control functions at both the tactical and operational level to become more mobile. One of the mechanisms to ensure the function of control was available as the battlefront advanced was to not only create and employ lightweight mobile radars, but also mobile operations rooms. The AN/TQ-1 and SCS-5 were two of the first portable information centers.[183]

The SCR-572 another mobile operations van, similar to a moving van, measured 27x8 feet and weighed 35,000 pounds. The operations room, located in the front of the vehicle, had a filter and operations table for identification purposes and three controllers; the Duty Controller, Deputy Controller and, Assistant Controller. There was sufficient communications equipment for each controller to monitor a channel, with the fourth controller at the switchboard. The operations room also housed the D/F unit and a mission board that provided the controllers information such as mission number, time of departure, mission type, number of aircraft, aircraft type, call signs, channel and objective via a grid coordinate. In effect, this solution allowed controllers to be somewhat mobile and provide control as ground forces advanced until more permanent facilities moved closer to the battlefront. The back of the vehicle housed the communication equipment.[184]

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182 AAFSAT Course Lecture, "GCI- AI Team," January 1944, Call # 248.25-8, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report, "History & Background of Night Interception," 1940, Call # 248.252-24, in the USAF Collection, AFHRA, Maxwell AFB, AL.

183 *Army Air Force Historical Studies No 13, The Development of Tactical Doctrine at AAFSAT and AAFTAC,* 56-57.; AAFSAT Course Lecture, "Offensive Control," February 1944, p. 4, Call # 248.25-1, in the USAF Collection, AFHRA, Maxwell AFB AL.

184 AAFSAT Course Lecture, "Offensive Control," February 1944, pp. 5-6, Call # 248.25-1, in the USAF Collection, AFHRA, Maxwell AFB AL.

Conclusion

The US grew from the inexperienced nation leaning on the British for technological assistance and doctrinal inputs to a nation employing a robust command and control system. The US ended the war in Europe with the most advanced ground radars, AI, and IFF of the war. America's geography not only gave it sanctuary from attack, but it also necessitated the need for mobile radar, which played a tremendous role in this war.

The US ably merged concepts from air-to-air and air-to-ground operations to create a command and control system for both defensive and offensive operations. Through 1942, air power fell under the control of ground commanders, but by the end of the war, air power was coequal. This allowed commanders the most flexibility to use airpower when and where needed as exemplified by the system's ability to redirect fighter or reconnaissance aircraft to destroy emerging targets or second priority targets before returning to base.

The command and control processes established before the war had to be adjusted based on battlefield experience. As the war progressed, the US became increasingly more effective. The command and control processes used by Ninth Air Force were the culmination of years of practice, adaption of British methods, and battlefield experience. These processes serve as the basis of today's theater air control system.

Technologically, the US quickly realized the importance of radios and radar and embarked on a rapid expansion in terms of production numbers and capability by leveraging British developments and those within the US industrial and university system, such as the MIT labs.

America also had outstanding leadership. Once field commanders became aware of the capabilities a command and control system brought to the battlefield, they demanded its presence and supported the growing roles fighter control played against enemy fighters, conducting air-to-ground operations, and supporting reconnaissance operations. Political leaders saw its capabilities as a way to track the V-1 and use fighters to knock the V-1 off course before reaching Great Britain. The US's doctrine evolved to be flexible, incorporating defensive and offensive needs. Although General Arnold was talking about the future of aerial warfare when he stated it would have "a communications system between control center and each individual aircraft will be established. Location and observation of targets, takeoffs, navigation and landing of aircraft, and communications will be independent of visibility or weather,"[185] by the end of WWII, Arnold's vision was practically realized.

Chapter 7

Germany WWII

Introduction

Germany entered World War II with a well functioning air-to-ground command and control system. It served as the model from which the UK and US built their respective air-to-ground command and control systems. Germany however, did not enter World War II well prepared from an air-to-air (air defense) command and control perspective. Germany had the largest air defense system in the world in terms of AAA and searchlights, but the command and control system to orchestrate the defense was not well developed. Despite a very rich and successful history in this area during WWI and a widespread eyes and ears Aircraft Reporting Service (ARS) heavily developed before the war, it was not prepared. Although able to inflict considerable damage on the Allies, Germany simply could not catch up from years of neglect. Undoubtedly, German decisions regarding aircraft production and an unrealistic assessment of the war's length also contributed to its failure.

[185] Arnold, *Third Report of the Commanding General of the Army Air Forces to the Secretary of War: 12 November 1945,* 67.

However, its air-ground command and control system was developed and well prepared for operations in Poland, and quickly improved for operations in France and then Russia. While Germany served as the model from which the British and Americans looked to regarding air-ground operations, Germany never really expanded its air-ground command and control system beyond the air control party concept. It never developed the fully integrated command and control systems as embodied in the American TACs and British 2 TAF. Resources were only a part of the reason; the other was a lack of vision. Regardless of this lack of vision, early in the war, with air superiority attained, the Luftwaffe's air-to-ground command and control system proved instrumental in Germany's success on the ground.

Air-to-Ground Cooperation

Luftwaffe success gaining air superiority allowed it to quickly shift the operational focus to supporting Army operations, specifically direct support operations. The Army's weakness in terms of artillery and anti-tank weapons led to a situation where the Army required Luftwaffe support to conduct operations. Over time, dependence increased as the Army weakened and enemy strength increased. Further dependence resulted from Field Marshal Kesselring's strong support of Army needs. He fully supported the Luftwaffe fulfilling the Army's requests, going so far as to say the generals should "consider the wishes of the Army as my orders." Mirroring the thought of airmen across the major belligerents, "the ruling viewpoint in Luftwaffe command circles was that air support for the Army would take the form of indirect support through action against the enemy rear rather than that of direct support on the field of battle."[1]

During the Polish campaign, von Richthofen commanded the Special Purpose Air Command (*Fliegerfuerhrer zur besonderen*

[1] Deichmann, *German Air Force Operations in Support of the Army*, 55, 125-127.

Verwendung) to support Army operations. This unit built on the efforts and insights gained in Spain. He then established four subordinate teams called Air Signal Detachments (*Luftnachrichtenverbindungstruppe*), whose purpose was to support Army requirements by working closely with the armored commander. Two of the four units used an armored car equipped with radios. Their success in Poland led to their widespread and successful use in France.[2]

Success drove the expansion of the system in terms of liaisons and communications connectivity. Overall, the procedures for ground control were relatively simple and straightforward. Execution of the processes however was difficult to execute properly and required extensive specialized training. Therefore, the Luftwaffe stressed the importance of liaisons, assigning two *Fliegerverbindungs Offizier* or *Flivos* at all command echelons, but they were not considered air advisors to the ground staff. Tactical Air Command controlled the *Flivos*. To control aircraft they used specially trained personnel called *Fliegerleit Offizier* (Ground Control Officer) and Signal Liaison Officers if the Ground Control Officer was unavailable. Signal Liaison Officers also had the responsible of operating and managing the communication equipment of the liaison team.[3]

The Luftwaffe heavily emphasized experience and training for these specialists. *Flivos* were ex-flyers with knowledge of signals and air tactics. The *Flivo* School was another two months of specialized training. The *Flivo* had with him an Intelligence Officer, Photo Officer and assistants, and a Signal Officer to assist in keeping the air command appraised of the ground situation. The *Flivo* (Signals) ran two radio sets

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[2] Ibid, 131.

[3] Report. *Air Staff Post Hostilities Intelligence, Requirements on G.A.F. Tactical Employment-Liaison Operations*, Call # 519.601B-4, Sec IV H, pp. 7, 12-13, in the USAF Collection, AFHRA, Maxwell AFB AL.; Oral Interview. *Lt Gen Heinz Gaedcke*, U.S. Air Force Oral History Program, 12 April 1970, Call # K239.0512-1180, p 5, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report. Air Staff Post Hostilities Intelligence Requirements on G.A.F. Tactical Employment, Call # 519.601 B-4 Section IV E Part 1, p. 60, in the USAF Collection, AFHRA, Maxwell AFB AL.

and served as a liaison. A *Flivo* (Reconnaissance) served as the liaison to reconnaissance units.[4]

Ground Control Officers, of which there were two types, Attack and Fighter, were experience pilots that also attended specialized training to conduct direct support missions. Ground Control Officers operated from tanks or armored vehicles near the front line and served as the direct link between aircraft and troops on the ground. The Ground Control Officer controlled strikes, directed mission changes, and updated aircraft with the latest ground intelligence. Radio provided the direct two-way link between the Ground Control Officer and the aircraft. The Ground Control Officer had to know the scheme of maneuver and the friendly line location, which proved problematic in a rapidly moving battlefront.[5]

For the Russian campaign, the detachments became known as Air Signal Liaison Detachments, now comprised of an Air Signal officer, a driver for the armored vehicle, and four dedicated radio operators to ensure 24-hour operations. Each Corps had its own Air Signal Liaison Detachment. Its primary purpose was to keep the Air Corps apprised of the ground situation to include targets and enemy and friendly positions. As discussed earlier, they could not conduct air strikes.[6] To deal with special situations on the Russian Front, the Luftwaffe created *Gefechtsverbaende*. These units worked extremely close with spearhead units at the *Schwerpunkt* of operations to control bombers, dive-bombers, and fighters in their efforts to help the Army breakthrough the enemy.[7]

Communication issues due to the size of the front and the dynamic

[4] *Air Staff Post Hostilities Intelligence, Requirements on G.A.F. Tactical Employment-Liaison Operations*, 7, 12.
[5] *Air Staff Post Hostilities Intelligence, Requirements on G.A.F. Tactical Employment-Liaison Operations*, 7-9, 13-14.
[6] Deichmann, *German Air Force Operations in Support of the Army*, 131-133.
[7] Report. German Translation No. VII/34, "Air Operations on the Russian Front in 1941," p. 3, Call # 512.621 VII/34, in the USAF Collection, AFHRA, Maxwell AFB AL.; Conduct of the Air War in the Second World War, 439.

nature of air-to-ground operations hampered effective operations. Bomb lines were difficult to find, but were done so with panels, special lights, orange colored smoke, flares, rockets, panels, and radio. German artillery observation planes used radios, but also dropped messages, using a smoke cartridge to assist in finding the message.[8] Many Luftwaffe units rarely had direct communication lines with Army Corps, and only did so if there were long planning times to make the connections. The arrival of wireless equipment en masse helped the liaisons, but overall the Air Signal Corps had trouble establishing good communications across the east's wide expanse.[9] To improve communications between the Luftwaffe and Army in support of reconnaissance operations, the Luftwaffe created Communications (*Kurier*) Squadrons to move message traffic and photos across the battlefield using various methods such as radio, cars, motorcycles, and airplanes.[10]

An example of a typical Tank Liaison (*Panzer Verbindung*) operation on December 12, 1942, near Medjez el Babi in North Africa best demonstrates the control process. The air liaison tank was located next to the staff tank and mobile radio van. The liaison managed radio messages to and from Panzer Headquarters and *Fliegerfuehrer* in Tunis. When the ground commander needed air support, the liaison officer passed the request to *Fliegerfuehrer* with the location and type of target, estimate of force required, and any air or ground opposition. The Panzer Headquarters listened on the same communications network. Once the *Stukas* took off, the *Fliegerfuehrer* notified the liaison officer via radio and shortly thereafter, the *Stuka* and liaison talked to each other about the target. Once over the target area, the liaison directed the aircraft to its target via radio using code words that changed daily. If necessary, the

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[8] *Air Staff Post Hostilities Intelligence, Requirements on G.A.F. Tactical Employment-Liaison Operations*, 7-8; Deichmann, *German Air Force Operations in Support of the Army*, 79, 135.
[9] Deichmann, *German Air Force Operations in Support of the Army*, 130, 162.
[10] Report. Air Staff Post Hostilities Intelligence Requirements on G.A.F. Tactical Employment, Call # 519.601 B-4 Section IV E Part 1, p 63, in the USAF Collection, AFHRA, Maxwell AFB AL.

liaison redirected the *Stuka*. Post mission reports followed to assess the effectiveness of the mission.[11]

The strain was too great however, and by winter 1942, "no units organic to the Luftwaffe would remain under tactical control by the Army." Tactical air support commands (*Koluft*) deactivated in 1943 resulting in an air corps supporting two or three Armies. By this time, most liaisons remained at the Corp level or higher.[12]

An increasingly critical air situation on the Russian front resulted in the establishment of fighter control under forward air control detachments for fighter forces, using Benito and EGON. There were six fighter control units (*Jaegerleitzuege*) using railway cars for mobility and integrating radar, ARS, and the radio interception service. These fighter control units usually operated in a defensive manner due to aircraft shortages and need to support ground operations.[13] However, theater size precluded covering the area with an adequate aircraft reporting service.[14]

Mirroring the American and British experience, the Germans also found that the best coordination occurred when Army and Luftwaffe headquarters were co-located. However, Germany lacked a joint command and control system and this proved especially detrimental on the eastern front. The existing command and control system, while at times tactically effective, was not efficient. "The Luftwaffe Command realized the harmful results of a system in which air operations were too

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[11] *Air Staff Post Hostilities Intelligence, Requirements on G.A.F. Tactical Employment-Liaison Operations,* 26-27.

[12] Oral Interview. *Lt Gen Heinz Gaedcke*.; Report. Air Staff Post Hostilities Intelligence Requirements on G.A.F. Tactical Employment, Call # 519.601 B-4 Section IV E Part 1, pp. 54, 59, in the USAF Collection, AFHRA, Maxwell AFB AL.; Deichmann, *German Air Force Operations in Support of the Army*, 84, 129-130.

[13] General Galland Interview, Part 6, "Air Ministry Weekly Intelligence Summary Issued By Air Ministry A.C.A.A (I)(A.I.I)," No. 318, 8th October, 1945, p. 12, Call # 512.6314U V.2, in the USAF Collection, AFHRA, Maxwell AFB AL.

[14] Deichmann, *German Air Force Operations in Support of the Army*, 162.

strictly contingent upon army operations."[15] Critical manning and equipment shortages contributed to the problem, as airpower became the solution to all ground problems. Overall, while the German command and control system for air-to-ground operations became the model from which the Americans and British based their system, the Germans did not leverage technology in the form of radios and radars to the same extent, nor establish an overall organizational command and control structure to exploit air power's strengths.

Organization

Overall Reich Defense Structure

A few days after the 1 September 1939 attack on Poland, the Luftwaffe relieved its fighters of air defense duties in the absence of attacks by the Polish air force. Aggressively attacking Polish air bases and planes, in line with doctrine, had achieved air superiority. The Luftwaffe felt the Polish Campaign vindicated the idea, expressed in L. Dv 16, that home defense alone cannot eliminate the threat.[16] In fact, changes to the 1940 version of L. Dv 16 were more administrative than substantive.[17]

On 4 September 1939, Britain conducted its first attack on Germany with twenty bombers. Radar information provided to the defensive fighters resulted in the downing of twelve bombers.[18] On 22 September 1939, a Directive from the Chief of the Luftwaffe ordered the two Air Fleets in the west to prepare for attacks against England. The Air Fleets were responsible for both offense and defense and thus for coordinating AAA and fighter operations at their level. No Luftwaffe wide standard existed for this coordination, resulting in different standards

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[15] Ibid, 128, 164.
[16] Ibid, 209-11.
[17] *L. Dv 16, The Conduct of Aerial Warfare (L.F),* 1940.
[18] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1,* 234.

between the two Air Fleets. As a result, fighter-AAA coordination throughout the war was not good and resulted in numerous fratricides.[19]

Germany believed it had a good air defense network, as evidenced by the 18 December 1939 shoot down of another twelve British bombers.[20] Continued British attacks increased throughout early 1940, thus increasing the emphasis on air defense.[21] This led to a coastal reporting network and increased integration between the Luftwaffe and the Navy, creating an integrated air defense network along the coastal region that relied heavily on human eyes and ears. The reliance on eyes and ears as the primary means of early warning, however, hampered radar development and integration.[22]

After the 9 April 1940 attack against Denmark and Norway, the Luftwaffe established the Special Air District Command (*Feldluftgau*) in Oslo, Norway to defend south and west Norway. Despite this new command district, very few fighters were included for Norway's defense since planning against France committed almost all fighters to offense. In May 1940, 2589 German bombers, dive-bombers, ground attack aircraft, fighters, and destroyers confronted 1453 allied bombers and fighters near the front.[23]

For Germany, the Battle for Britain began on 13 August 1940, and on 18 December 1940 with Britain still not defeated, Hitler issued the directive for Barbarossa, the attack on the Soviet Union. The Luftwaffe

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[19] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2,* 234-36a.; "German Day-Fighting in the Defense of the Reich from Sep 15 1943 to the End of the War," Interrogation of Beppo Schmid, p. 5, Call # 512.645G, in the USAF Collection, AFHRA, Maxwell AFB AL.

[20] Alfred Price, *Instruments of Darkness* (London,: Kimber, 1967), 61-62.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2,* 270-72.

[21] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2,* 290a.

[22] Office of A.C. of S. HQ USAFE, A-2, "The German Air Force Aircraft Warning & Fighter Control System," in *Air Staff Post Hostilities Intelligence Requirements of the German Air Force* (Maxwell AFB, Alabama: Air Force Historical Research Agency, 1 December 1945), p. 17, Call # 519.601B-4 Section IVB, Vol I, in the USAF Collection, AFHRA, Maxwell AFB AL.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2,* 292.

[23] Karl-Heinz Frieser and John T. Greenwood, *The Blitzkrieg Legend: The 1940 Campaign in the West* (Annapolis, Md: Naval Institute Press, 2005), 47-48.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2,* 274-76, 80-81.

now began focusing on eastern offensive actions.[24] The start of Barbarossa left only Luftflotte 3 with two fighter wings in the west and one fighter group in Heligoland. There were no defensive fighters over Germany, with all of Luftflotte 3's fighters located in Belgium and the Netherlands.[25] Despite all this activity, in September 1941, the Luftwaffe General Staff thought a production rate of 360 fighters per month still enough for all necessary missions.[26]

From the beginning of WWII until 1940, Air Region Commands or Air Force Administration Commands, (*Luftgaukommandos*), conducted the air defense mission in a decentralized manner in their area of responsibility. Air defense, comprised mostly of AAA (doctrinally fighters were used for offensive operations), used the air signal communications and air raid warning services. The Navy also had its own air defense sectors.[27] In September 1940, General der Flakartillerie Hubert Weise took command of Luftgau III in Berlin with the task of consolidating air defense under a single command. Over time, this command grew to become Reich Air Defense.[28]

On 24 March 1941, the Air Force Command Center (*Luftwaffenbefehlshaber Mitte*) emerged under General Weise's command. AFCC had the Night Fighter Division and Luftgaukommandos III, IV, VI, and XI, with VII, XII, and XIII added later. These Luftgaukommandos fell under the newly created AFCC, controlling AAA, signals, air raid warning

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[24] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2,* 318.
[25] Hans-Detlef Herhudt von Rohden, *European essays on the history of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey* (August, 1946).
[26] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2,* 318a.
[27] von Rohden, *European essays on the history of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey*.; "The German Air Force in Maps and Diagrams 1939-43," *Air Publication 3038* (November, 1943), Call # 512.6314T, p. 66, in the USAF Collection, AFHRA, Maxwell AFB AL.; The German Air Force Post Hostilities Course, "The German Air Force," by Lt Col D. M. Pearson, 1944, Call # 512.6314B, p. 10, in the USAF Collection, AFHRA, Maxwell AFB AL.; von Rohden, *European contributions to the history of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 13.
[28] Air Prisoner of War Interrogation Unit Reports, "Luftflotten Kommando Reich," 28 May 1945, Air P/W Interrogation Unit. Main Headquarters. Second TAF. Call # 515.619-1 V3, p. 2, in the USAF Collection, AFHRA, Maxwell AFB AL.

defense, and aircraft warning.[29] That same month, a directive gave Air Force Command Center and the Luftgaukommandos the responsibility for air defense in each of their respective areas with fighters assigned to each of them, finally providing some centralized control of air defense.[30] Night fighting fell under the Night Fighting Division in 1940, becoming XII Fliegerkorps in 1941, while in 1942 day fighting fell under Jagdfliegerfuehrer of Central Germany (Berlin), Deutsche Bucht, and Ruhr.[31]

By early 1944, Air Force Reich (*Luftflotte Reich*) replaced AFCC commanding all air defenses[32] and the various reporting and warning organizations finally unified under I Fighter Corps on 1 February 1944, but connecting the disparate organizations took until spring 1945.[33] Beginning 1 February 1944, the Fighter Divisions created the central situation map and transmitted the resultant information to other organizations. I Fighter Corps and Air Force Reich provided additional information as necessary.[34] The second major change in February 1944 moved the aircraft warning service from under the Air Signal Corps to the

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[29] von Rohden, *European essays on the history of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey*.; "The German Air Force in Maps and Diagrams 1939-43," *Air Publication 3038* (November, 1943), Call # 512.6314T, p. 66, in the USAF Collection, AFHRA, Maxwell AFB AL.; The German Air Force Post Hostilities Course, "The German Air Force," by Lt Col D. M. Pearson, 1944, p. 10, Call # 512.6314B, in the USAF Collection, AFHRA, Maxwell AFB AL.; von Rohden, *European Contributions to the History of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 15.; 5125.619-1 V3, p. 2.

[30] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2,* 319.; von Rohden, *European Essays on the History of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.*

[31] Air Prisoner of War Interrogation Unit Reports, "Luftflotten Kommando Reich," 28 May 1945, Air P/W Interrogation Unit. Main Headquarters. Second TAF. Call # 515.619-1 V3, p. 3, in the USAF Collection, AFHRA, Maxwell AFB AL.

[32] von Rohden, *European essays on the history of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.*

[33] Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, p 30, in the USAF Collection, AFHRA, Maxwell AFB AL.

[34] von Rohden, *European contributions to the history of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 97.; Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," p 25, Call # 512.645-5, in the USAF Collection, AFHRA, Maxwell AFB AL.

I Fighter Corps.[35]

Aircraft Reporting Service

The Aircraft Reporting Service (ARS) fell under the Air Signals Corps in May 1938 due to the Corps' management of the existing telephone infrastructure. At the start of the war, the ARS consisted of two organizations: one for the troops and one for the Reich.[36] The troop warning service provided air defense in the operational zone of the army. It contained air warning companies (motorized) and an air warning section of the signal communications corps. These rear elements of the Army zone connected to the home defense network.[37] The latter, called the Air Raid Warning Service, received orders from the General Staff of the Air Force, but was executed by the police.[38]

By 1942, despite overall air defense successes against the British, the German warning system had performed poorly.[39] Enemy reporting was very fragmented, the ARS had no radar, and every organization spent resources to have its own "air picture," to include the ARS, night fighters, AAA (AA Spotting Service), Y-Service, local Air Warning Stations, the Navy, the police, and political leaders.[40] There were four autonomous warning services; *Flugmeldedienst*, Navy, Nazi Party, and Railway Service (*Reichsbahn*).[41] A separate radar detection system (*Funkmessdienst*) and a fighter control system (*Jaegerleitsystem*) gathering information also

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[35] von Rohden, *European contributions to the history of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 67.

[36] Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, p 28, in the USAF Collection, AFHRA, Maxwell AFB AL.

[37] von Rohden, *European contributions to the history of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 10.

[38] von Rohden, *European contributions to the history of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 9.; Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, p 28, in the USAF Collection, AFHRA, Maxwell AFB AL.

[39] von Rohden, *European essays on the history of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey*.

[40] Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, pp 24, 26, 29, in the USAF Collection, AFHRA, Maxwell AFB AL.

[41] Hooton, *Eagle in Flames*, 123.

existed.[42]

Control of the Reich ARS initially fell under the *Luftgaue*, which connected to each other and the territorial *Luftgaukommando* by wire. The ARS used filter centers, acoustic devices, and observer posts manned by the police and elderly reservists that were generally poorly trained. The situation worsened as experienced personnel, fit for service, moved to front line fighting units.[43] Normally, the ARS established itself around important areas rather than in a line type defense as the British had done or how the (German) fighter control areas were established. The ARS, mainly an eyes and ears service, had no radar until 1944 when it became subordinate to I Fighter Corps.[44] Conversely, the fighter control service received its information from the radar services. Through 1941, the wings were responsible for their own air situation maps, and then Fighter Corps became responsible, followed finally by the Fighter Divisions.[45] This method contrasts to the centralized "air picture" maintained by the British and Americans to ensure all subordinate units had the most current and complete information.

In 1943, General "Beppo" Schmid recommended to the High Command of the GAF a unified Reich ARS with Fighter Corps, Flak and fighter controller officers operating from the same operations room, and the fighter controller able to give orders to Flak.[46] Information on aircraft

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[42] von Rohden, *European essays on the history of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.;* Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, p 29, in the USAF Collection, AFHRA, Maxwell AFB AL.

[43] Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, pp. 27, 29, in the USAF Collection, AFHRA, Maxwell AFB AL.

[44] von Rohden, *European contributions to the history of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 10.; Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, p 28, in the USAF Collection, AFHRA, Maxwell AFB AL.

[45] Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, p 25, in the USAF Collection, AFHRA, Maxwell AFB AL.; von Rohden, *European essays on the history of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.*

[46] Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, p 60, in the USAF Collection, AFHRA, Maxwell AFB AL.

movement came from various sources such as take off reports, Fighter Division controllers, fighter position reports, ARS eyes and ears data, IFF and the Y-Service.[47] Each Jaegerdivision headquarters finally received a Flak officer at the end of 1944 to coordinate between Flak and fighters, which appeared to improve coordination.[48] In a post war report, General Schmid stated he did not think the Luftwaffe solved the problem of integrating all the data into a command and control system.[49]

Signal Intelligence

As it did during WWI, German signal intelligence (*Funkhorchdienst*) or "Y-Service," performed a critical role during the war and its integration, or lack thereof at times, proved crucial. The radio monitoring service provided valuable information on enemy strength, disposition, and action such as incoming allied bombers, to include the ability to monitor British pre-flight checks. The Y-Service had the ability to accurately distinguish and plot aircraft throughout their mission by triangulating allied radar, radios, IFF, and jamming emissions. Signal intelligence helped commanders make critical and timely decisions by providing a very accurate air situation map based on bomber and fighter communications.[50] The Y-Service also discovered that British aircraft were receiving guidance from ground controllers during the Battle of

[47] Ibid, p 24.

[48] General Galland Interview, Part 8, "Air Ministry Weekly Intelligence Summary Issued By Air Ministry A.C.A.A (I)(A.I.I)," No. 318, 8th October, 1945, p. 1, Call # 512.6314U V.2, in the USAF Collection, AFHRA, Maxwell AFB AL.

[49] Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, p 24, in the USAF Collection, AFHRA, Maxwell AFB AL.

[50] Kammhuber, "USAF Historical Studies: No. 179, Problems in the Conduct of a Day and Night Defensive Air War," 22; "Combined Operational Planning Committee. Sixteenth Period Report on Enemy Daylight Fighter Defenses and Interception Tactics. Period 1 April, 1945 – 30 April, 1945," Report from March 19, 20, 21, 1945, Call # 168.7020-29, in the USAF Collection, AFHRA, Maxwell AFB AL.; Air Defence of Great Britain Intelligence Memorandum, "Notes on the G.A.F Day Fighter System in Western Europe," Call # 512.662, p. 16, in the USAF Collection, AFHRA, Maxwell AFB AL.; "German Day-Fighting in the Defense of the Reich from Sep 15 1943 to the End of the War," Interrogation of Beppo Schmid, p. 2, Call # 512.645G, in the USAF Collection, AFHRA, Maxwell AFB AL.; E. S. Henning, *The High Frequency War: A Survey of German Electronic Development*, (Headquarters Air Material Command, Wright Field Dayton, Ohio, 10 May 1946), 35.; von Rohden, *European contributions to the history of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 82, 98.; Hooton, *Eagle in Flames*, 112.

Britain, providing Germany clear evidence of British radar and the existence of a command and control system.[51]

The Y-Service operated as mobile intercept companies with “four receivers, three D/F trucks for long and medium waves, three transmitter vans each fitted with a small plotting room and a communications section.” Approximately 90 personnel comprised a company.[52]

Reflective of the Nazi culture of control and organizational empire building, conflict arose between the head of the Air Signal Corps, General Martini and General Schmid. At times, information on allied raids from the Y-Service was notoriously slow in arriving on time, sometimes the next day. After assuming command, General Schmid developed a process whereby Y-Service information reached the fighter controllers in real time. The controller now used real time data plots to make an intercept. General Martini wanted all information passed to the front to first go through Paris and then to I Fighter Corps. When General Schmid protested, General Martini simply removed the radars and Y-Service personnel from General Schmid’s area,[53] depriving Schmid’s units of the critical information.

Processes

While all three countries developed processes based on their technology, organization, and other factors, the broad processes developed by the three were generally the same. Early warning radars, observers, and a system of sending information to a central plotting room to provide an operational picture served as the basis of the German

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[51] General Galland Interview, Part 2, “Air Ministry Weekly Intelligence Summary Issued By Air Ministry A.C.A.A (I)(A.I.I),” No. 314, 10th September, 1945, pp. 10-11, Call # 512.6314U V.2, in the USAF Collection, AFHRA, Maxwell AFB AL.

[52] Henning, *The High Frequency War: A Survey of German Electronic Development*, 38.

[53] Post-Hostilities Report of General Joseph Schmid, “Night Fighter Operations,” Call # 512.645-5, p 25, in the USAF Collection, AFHRA, Maxwell AFB AL.; von Rohden, *European contributions to the history of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 82.

command and control system.[54] Information came from radar stations, the air raid warning service, direction finders, listening posts, and fighter and reconnaissance units into the fighter control stations and central headquarters via radio or telephone. These processes were a continuation of those first developed by Germany during WWI, but Germany failed to develop them fully before the start of the war.

Origins of German Fighter Control

Understanding the processes of the German fighter control system and hence their command and control system requires understanding how the Luftwaffe distinguished between fighter control methods or procedures (*Verfahren*) and fighter control technical means. Germany also distinguished between day and night fighter control. The period through 1941 saw the development of the following procedures or methods for night fighter control due to the inherent difficulties of night interception; *Helle Nachtjagd*, *Kombinierte Nachtjagd*, and *Dunkel Nachtjagd (Himmelbett*). The same period saw the development of the following fighter control technical means; *Reportage Verfahren*, *AN-Verfahren*, and *Seeburg-Verfahren*. Day fighter control relied mainly on a method referred to as broadcast control, running commentary, or "*Jäger Reportage*."

Initially, German fighter pilots resisted the concept of fighter control, but eventually realized the critical importance fighter control played in destroying enemy aircraft. Despite initial resistance, fighter control in the Luftwaffe was a bottom up development rather than top down driven as in the UK, where men in the field searched for ways to cope with British night attacks. One of these men, Lt Hermann Diehl, led an experimental radar group on the island of Wangerooge when on December 18, 1939 he used a Freya radar to locate and intercept RAF bombers. This led directly to the techniques that became the basis of

[54] Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 187-188.

German fighter control.[55] These techniques, however, were not ready or employed during the Battle for Britain.

Helle Nachtjagd

The Germans viewed night fighting as an almost impossible task, last examining the possibility in the summer of 1939. The British night bombings sparked a self-initiated re-evaluation by German units.[56] Between 20 April and 3 May 1940, Captain Wolfgang Falck began conducting night fighting experiments from Aalborg, Denmark to counter growing British night bombing missions. Falck conducted these experiments with no direction from higher command authorities. He worked out procedures to orbit and receive intercept vectors from a controller who had picked up the enemy on radar. On 26 June 1940, Captain Falck presented his night intercept concept to Reichsmarschall Göring, General Albert Kesselring, and General Ernst Udet. Despite the lack of a kill, Falck's success in intercepting British bombers highlighted the need to centrally control radar, the aircraft reporting services, searchlights, FLAK and fighters, resulting in the 1st Night Fighter Division's (*Nachtjagddivision*) creation under the Second Air Fleet on 17 July 1940 with Colonel Josef Kammhuber as its commander. The new *Nacht-undVersuchs Staffel* (Night and Experimental Squadron) under Major Falck led the development of night fighting techniques.[57]

Colonel Kammhuber immediately began building an air defense organization. The 1st Night Fighter Division became the XII *Fliegerkorps* (Flying Corps) on 10 August 1941 and Captain Falck received command of the 1st Fighter Wing. Upon its creation, the 1st Night Fighter Division

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[55] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 90.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2*, 240.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 324.; von Rohden, *European contributions to the history of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 13.; Henning, *The High Frequency War: A Survey of German Electronic Development*, 23.

[56] Air Ministry, *The Rise and fall of the German Air Force, 1933-1945*, 185.

[57] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2*, 288a.; Aders, *History of the German Night Fighter Force, 1917-1945*, 20.; Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 185-186.

had only one searchlight regiment, the 1st Searchlight Regiment near Düsseldorf, working with it, but within a year it had six searchlight regiments. The Searchlight Regiments were under the control of the Air District Commander.[58] On 20 July 1940, the unit achieved its first successful night intercept. One result of this success was a directive issued the next day for all fighters to establish night fighting capabilities.[59] Falck's system became known as *Helle Nachtjagd*, or "illuminated night combat." Unlike the first experiments, *Helle Nachtjagd* did not initially use fighter controllers. A searchlight belt was placed 18 miles forward of the AAA zone. Fighters orbited on standby outside the searchlight area on the side or in front of the searchlights, since engine noise affected acoustic pickup. Fighters orbiting outside the searchlight area flew to the general area of the enemy and attacked when searchlights indicated an approaching bomber raid. Air defense fighters had about three minutes to attack the bomber from above and the rear or side before it passed through the illuminated area. It was difficult to intercept aircraft with this system. The British quickly adapted and simply flew around the few available searchlights.[60] This system, lacking fighter control, used *Reportage Verfahren* (Reporting Procedures), which entailed receiving whatever information was available via radio to infiltrate the bomber stream.[61]

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[58] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2*, 288a.; Aders, *History of the German Night Fighter Force, 1917-1945*, 20.; Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 186.

[59] Aders, *History of the German Night Fighter Force, 1917-1945*, 15-16, 18, 20, 42.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2*, 288, 88a, 34-35, 94.; Werner Held and Holger Nauroth, *The Defense of the Reich : Hitler's Nightfighter Planes and Pilots* (New York: Arco, 1982), 7-8.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 282.; von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 100.

[60] Aders, *History of the German Night Fighter Force, 1917-1945*, 18,20.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2*, 293-94.; Birkhold, "Enemy Radar."; Kammhuber, "USAF Historical Studies: No. 179, Problems in the Conduct of a Day and Night Defensive Air War," 51- 52.

[61] "Oberkommando der Luftwaffe Lw.-Fuehrungsstab Ausb. Abt. Nr. 1410/44 geh, "Reichluft-Verteidigung," Heft 2, 27-28.

Difficulties led to the view in late 1940 that controlled night fighting offered a better solution. This method used a dedicated fighter controller and tied the fighter to an area within radar's view.[62] During this time, experiments along some coastal areas used the Freya with a supplementary control set, the *Freya Gerät mit AN- Führungszusatz*, or simply the AN-Freya. This system, used in areas lacking searchlights, facilitated fighter and bomber track plotting on a plotting table, followed by vectors from a fighter controller to the fighter.[63] The Würzburg-Riese, with its appearance in 1941, gave the AN-Freya its height capability.[64] The controller saw target echoes vertically on a cathode ray tube and lined up the target and fighter echoes to get the fighter within 50-meters of the target.[65] Slow delivery of the AN-Freya relegated this technique, known as AN-Verfahren, to minimal use, although coastal radar stations continued using the AN-Freya.[66]

On 16 October 1940, the 1st Night Fighter Division received its first Würzburg-A to guide night fighters to a bomber using radio and searchlights. The Division established three night fighting zones in a 90 x 20 km area near the Zuider Zee. Fighters now orbited in the middle of searchlight areas to improve their chances of success.[67] When the Würzburg detected the incoming target, the fighter controller directed the fighter to the area. This method was not very effective due to a shortage of radars and fighter controllers, and led to vocal arguments within the Luftwaffe regarding controlled fighter intercepts. General Kammhuber regarded uncontrolled intercept ineffective and viewed the current problems in terms of a lack of equipment and not a deficiency in concept.

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[62] Aders, *History of the German Night Fighter Force, 1917-1945*, 19.
[63] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2*, 303-04.
[64] "Oberkommando der Luftwaffe Lw.-Fuehrengsstab Ausb. Abt. Nr. 1410/44 geh, "Reichluft-Verteidigung," Heft 2, 26.
[65] Aders, *History of the German Night Fighter Force, 1917-1945*, 22-24.
[66] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 24.
[67] Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War, 52.*; Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 186.

Pilots wanted two Würzburgs, one to track the fighter and one to track the bomber, thinking this would be effective.[68] As more Würzburgs became available in November 1940, two Würzburgs per area became the norm. Controllers conducted intercepts from track information displayed on simple plotting tables, a method deemed primitive.[69]

These early experimental areas with fighter control were heavily used from January to June 1941, eventually comprising 18 sectors, each 45 km (30 miles) wide, and 35 km (20 miles) deep running from Hamburg to Luttich. By the fall of 1941, this system stretched from Denmark to Maubeuge and Frankfurt to Mannheim. By the end of 1942, it ran from Paris to Northern Denmark, along the German coast, and over Berlin. The British called it the Kammhuber Line. Each sector contained a searchlight, a communications company, three fighters, a Freya, and three Würzburgs, one in the front, middle, and end of the zone. The Freya tracked incoming aircraft beginning at 90 miles and handed the target data to the Würzburgs for detailed tracking. Searchlight batteries illuminated the target from data received from the Würzburgs. One airborne fighter conducted the intercept, with a second on runway alert and a third in reserve.[70]

This system worked well initially when the British bomber streams flew extended formations over a wide front, but the Würzburg's limited range, imprecise data transfer to plotting boards, and lack of IFF created problems, as did the British ability to quickly counter this new system. The British countered this system by diving through or around the searchlights, eventually forcing the Germans to devise new intercept procedures and equipment.[71] These problems led now Generals

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[68] Aders, *History of the German Night Fighter Force, 1917-1945*, 25.; Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2*, 303.
[69] Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 57-58.; Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 187.
[70] Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 187-188.
[71] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 282.; Held and Nauroth, *The Defense of the Reich : Hitler's Nightfighter Planes and Pilots*, 33.; Birkhold, "Enemy

Kammhuber and Martini to request better radar, improved plotting tables, IFF and AI.[72]

Although the Würzburg-A provided better success than no radar at all, searchlights were still required because the Würzburg-A did not provide sufficiently accurate track data. The Würzburg-C and Würzburg–Ds brought improved results without searchlights due to better accuracy and increased range of 25 km.[73] Fighter control with the Würzburg-Riese, introduced in September 1941, proved accurate enough for day and night fighter control operations.[74] Accuracy coupled with increased range led to an increase in sector size from 40 to 90 km, creating 10 zones in the West. These sectors had a Searchlight Regiment each with three detachments with one radar set and a post. The zone had a 36 km dark area ahead of each lighted area. This system took until the spring of 1942 to become effective.[75]

Kombinierte Nachtjagd

In the summer of 1940, experiments in another intercept method began that became operational in mid-1941, called *Kombinierte Nachtjagd*. This method concentrated around Kiel, Bremen, Hamburg, Koln, Düsseldorf-Essen-Duisburg, Wiesbaden-Frankfurt-Mannheim-Darmstadt, and München--all areas of industrial importance. Circular zones around the cities were subdivided into six sectors of 60 degrees each to include a small ring for the city center. Each sector had a night fighter. The AAA division headquarters had responsibility for aircraft below 5000 meters (18,040 ft) and plotted the target information on a Seeburg table as blue and red lights onto frosted glass. Once searchlights

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Radar."; von Rohden, *European essays on the history of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.*

[72] Aders, *History of the German Night Fighter Force, 1917-1945*, 33.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 324.; Kammhuber, "USAF Historical Studies: No. 179, Problems in the Conduct of a Day and Night Defensive Air War," 58.

[73] Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 58.

[74] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2*, 304-05.; Aders, *History of the German Night Fighter Force, 1917-1945*, 34-35.

[75] Aders, *History of the German Night Fighter Force, 1917-1945*, 34-35.

illuminated the aircraft, and the fighter entered the area, the AAA stopped firing and the fighter attempted to intercept the enemy. The major problem with this method was fratricide.[76] Fighters did not pass information to Flak units or vice versa and the air raid warning service did not always pass identification of friend or foe.[77] These coordination problems continued throughout the war.

Dunkel Nachtjagd

Experiments in the *Dunkel Nachtjagd*, or "dark night combat," fighter control method began in July 1940, paralleling the *Helle Nachtjagd* method. *Helle Nachtjagd* was completely dependent on the weather. Earlier detection was required to give the air defense fighters more time to intercept the incoming bombers and to counter British tactics, but weather affected searchlight operations. To be effective in weather, *Dunkel Nachtjagd* required technical equipment to locate the target.[78] The control system and organization needed to adapt quickly to the changing battle.[79] To enhance flexibility and the ability to intercept enemy aircraft regardless of the weather, General Kammhuber concluded his forces must be able to operate independent of weather. This required radar to measure distance, azimuth, and height, AI with auto guidance, and ground plotting stations with a headquarters for control.[80]

Dunkel Nachtjagd, variously known as *Himmelbett*, *Himmelbettverfahren*, limited area combat system, or controlled area fixed night fighter defense, had several major elements and consisted of a 20-40 mile circular area. It consisted of a headquarters, radars, AI, IFF, radios, plotting table, and the fighter aircraft. Information on enemy

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[76] Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 91-93.; Held and Nauroth, *The Defense of the Reich : Hitler's Nightfighter Planes and Pilots*, 71.; Aders, *History of the German Night Fighter Force, 1917-1945*, 36-37.

[77] von Rohden, *European contributions to the history of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 66.

[78] Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 49, 53-55.

[79] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 114.

[80] Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 56.

aircraft came from short and long range reporting centers, visually, acoustically, and from radars. One Freya radar usually equipped with the AN DF equipment found the enemy at long range and then passed the enemy track to a Würzburg-Riese labeled as the Würzburg Red. The Freya and Würzburg Red linked together to smoothly hand enemy data from one radar to the next. Once the Freya passed the track to the Würzburg Red, it could search and track a second enemy aircraft. Plotted track information on a board allowed prioritization and contained enemy information from all available sources. The Seeburg Table indicated the enemy track with a red light on the Seeburg when it became available.[81]

A second Würzburg–Riese, labeled Blue, tracked the friendly fighter. The fighter received voice commands over a short wave radio while a low power radio beacon over the Würzburg Blue marked the marshal area. The blue fighter orbited in the area, conducted radio checks, and waited for the enemy aircraft. When the enemy came into view, the intercept began. The Würzburg Blue tracked the friendly aircraft whose track information appeared as a green light on the Seeburg Table. This information, coupled with the information from the enemy track, gave the controller visual information on the two targets.[82] The use of two Würzburg-Riese and the Seeburg Table became known as *Seeburg-Verfahren.*[83]

Early information from the Freya improved the chances of a successful intercept, placing the fighter 3 km behind, slightly offset, and

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[81] HQ USAFE, "The German Air Force Aircraft Warning & Fighter Control System," 130.; Kammhuber, "USAF Historical Studies: No. 179, Problems in the Conduct of a Day and Night Defensive Air War," 64-65.; Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, pp. 70-71, in the USAF Collection, AFHRA, Maxwell AFB AL.; von Rohden, *European Essays on the History of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.;* Great Britain, *The Rise and Fall of the German Air Force, 1933-1945*, 187.
[82] Aders, *History of the German Night Fighter Force, 1917-1945*, 57.
[83] Oberkommando der Luftwaffe Lw.-Fuehrengsstab Ausb. Abt. Nr. 1410/44 geh, "Reichluft-Verteidigung," (Freiberg, Germany: Bundesarciv/Militararchiv RL2II/366, September 1944), Heft 2, 26.; HQ USAFE, "The German Air Force Aircraft Warning & Fighter Control System," 130.

below the enemy to see it illuminated against the night sky. Once the dots on the Seeburg table merged, the aircraft could still be 400 meters apart. The controller then called "Pauke, Pauke" (literally, "kettledrums, kettledrums"). If the fighter saw the enemy first, he called "Ready, Pauke, Pauke." In either case, this meant the controller could prepare for the next intercept. The Lichtenstein B/C AI radar played an important and critical role in increasing the intercept success rate.[84]

The new system had several disadvantages. Each zone could control only one fighter making it difficult to attack multiple bombers in the small area, it took time to replace dropped out fighters, and the fighter had to return to the marshaling beacon to be picked up by the Würzburg Blue. Concentrated bomber streams could also overwhelm each sector's radar while the lack of IFF and inexperienced fighter controllers made the system less than optimal.[85]

Additionally, Germany's lack of a PPI severely degraded its air defense and fighter control capabilities. The Seeburg Table took the place of the PPI, handling plots within a 36 km/22.4 mile radius that it received from the two Würzburg-Riese radars. The radars provided detailed track information that personnel fed manually into a computer. Automation using the Askania device was a later upgrade. To convert bearing and range data into a useful plot, the information appeared as a spot of red and green lights on an area map located at each command post. Linked to the Würzburg by telephone, operators controlled the lights, moving them as the data updated. At the table, others traced the tracks with grease pencils from which the controller, standing above the

[84] Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 66-69.
[85] Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, pp. 70-71, in the USAF Collection, AFHRA, Maxwell AFB AL.; Aders, *History of the German Night Fighter Force, 1917-1945*, 58.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 304.; Great Britain, *The Rise and Fall of the German Air Force, 1933-1945*, 188, 275-276.

table, vectored the fighters with altitude plotted on a vertical opaque glass screens via manual or auto inputs from the Askania device.[86]

By 1942, a searchlight belt ran from Jutland to the Swiss border with an additional 200 km deep night fighting zone in front and behind the searchlight belt.[87] Allied bombing began extracting a political cost to the German defense and fighter control system. In spring 1942, the Gauleiters petitioned Hitler for searchlights in their areas, resulting in the searchlights used in Helle Nachtjagd returning to the targeted cities.[88]

By June 1942, the searchlights redeployed from the front lines and returned to Germany's interior to protect the major industrial cities. *Hellenachtjagd* was no more. This forced the development of new techniques, especially with night fighter control, and resulted in the dissolution of the Searchlight Division on 31 July 1942.[89] More radar sets filled the gap left by the missing searchlights. Despite replacement with these additional radars, the withdrawal of searchlights in the spring of 1942 constituted a severe blow to the air defense, from which General Kammhuber claims the Luftwaffe never recovered. This drove the need for new techniques for fighter control because the searchlight areas accounted for 75% of the kills, while the dark areas accounted for the other 25%. Now all searchlight areas became dark areas. The lack of the Lichtenstein B/C AI by spring 1942 in the majority of German fighters contributed to this problem. It took until the fall of 1942 to get the overall kill rate back to the level achieved in early 1942.[90]

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[86] Buderi, *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution*, 203-04.; Aders, *History of the German Night Fighter Force, 1917-1945*, 33-34.; Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 184.
[87] Aders, *History of the German Night Fighter Force, 1917-1945*, 57.
[88] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 304.; Aders, *History of the German Night Fighter Force, 1917-1945*, 35.
[89] Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 49, 56, 61.; Aders, *History of the German Night Fighter Force, 1917-1945*, 35.
[90] Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 61-62.

Throughout 1942, the British still flew dispersed in long trails, but this soon changed. Tightened formations led to compressed time and mass within the defensive boxes. The fixed *Himmelbett* areas and procedures did not allow fighters assigned to one area to operate in an adjacent area. As a result, concentrating bombers into one area (the bomber stream) overwhelmed the air defenses.[91] In May 1942 for example, during an attack on Koln, only eight *Himmelbett* cells were touched and only 44 of 1000 bombers were destroyed by fighters and FLAK. Many fighters just orbited in their cells. In the end, H*immelbettverfahren* proved inflexible due to the inability to move radars, adjust to compressed British bomber flows, the use of window, and lack of long range radar entering the war in sufficient time and numbers (such as the *Wasserman* and *Mammut*) to have allowed for the creation of deeper engagement areas.[92]

By 1942, German day and night fighter operations used different procedures and technical means for fighter control. The day fighters wanted to use the EGON fighter control system while the night fighters opted to use the Y-Verfahren or Benito system coupled with *Himmelbett* procedures. This insistence introduced redundancy into the system, but required more personnel to train, maintain, and operate the equipment. Additionally, the multitude of equipment proved a strain on German industry.[93] By 1944, German doctrine still divided fighter control into day fighting and night fighting. Although very similar, there were slight differences. Night fighting was divided into four procedures or methods; *Ortsgebundene Nachtjagd* (*Himmelbett*), *Verfolgungsnachtjagd* (*Zahme Sau*), *Helle Objektnachtjagd* (*Wilde Sau*) and (*Lange Kerle*). Lange Kerle

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[91] von Rohden, *European Essays on the History of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey*.; Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 78.
[92] von Rohden, *European Essays on the History of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.;* Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 188, 275-276, 278.
[93] HQ USAFE, "The German Air Force Aircraft Warning & Fighter Control System," 39.

was simply attacking allied aircraft as far out from Germany as possible, usually British airfields or sometimes halfway across the North Sea. Day fighting used three technical means for fighter control: *Y-Führung*, *Erstling-Weitführung*, and *UKW-Peil-Führung*. Night fighting used *AN-Verfahren*, *Seeburg-Verfahren*, and *Y-Verfahren.*[94]

Wilde Sau

German frustration with the effectiveness of window jamming and improved bomber tactics led to the creation of the *Wilde Sau* (Wild Boar) tactics. The tactic, technically referred to as "non-controlled object fixed fighter defense," was mainly used from 25 July 1943.[95] While the pilots may have felt this was an effective method, General Kammhuber disapproved of this tactic, and described the method as a free for all firing of AAA and fighters. He felt controlled intercepts were more effective than non-controlled intercepts. With *Wilde Sau* tactics, fighter controllers vectored a lead fighter to the bomber stream and all other fighters simply followed and engaged the enemy bombers within the stream using AI or after visual acquisition using the moon or searchlights for lighting.[96] This system was highly dependent on the weather because it relied mainly on light from the moon or searchlights.[97]

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[94] Oberkommando der Luftwaffe Lw.-Fuehrengsstab Ausb. Abt. Nr. 1410/44 geh, "Reichluft-Verteidigung," Heft 2, 21-27.; Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 192, 280.; Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, p 73, in the USAF Collection, AFHRA, Maxwell AFB AL.

[95] Aders, *History of the German Night Fighter Force, 1917-1945*, 94.; von Rohden, *European Contributions to the History of World War II, 1939-1945; The War in the Air. Reich Air Defense, 1939-1945; A Strategic-Tactical Survey*.; von Rohden, *European Essays on the History of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.*; Great Britain, *The Rise and Fall of the German Air Force, 1933-1945*, 277.; Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, p 72, in the USAF Collection, AFHRA, Maxwell AFB AL.

[96] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 304-05.; Kammhuber, "USAF Historical Studies: No. 179, Problems in the Conduct of a Day and Night Defensive Air War," 88, 95-96.

[97] Oberkommando der Luftwaffe Lw.-Fuehrengsstab Ausb. Abt. Nr. 1410/44 geh, "Reichluft-Verteidigung," Heft 2, 22-23.

Another method used FLAK to first attack incoming bombers and then searchlights to assist the fighters in their attack, but coordination problems between FLAK and fighters continued to exist.[98] In this technique, German fighters waited near the expected target instead of attacking on the German periphery and attacked only after the bombers dropped their bombs. The bombers tended to scatter after an attack and the fire from the target area enhanced visual acquisition.[99] This method proved very effective against returning bombers.[100] Although German cities did sustain considerable damage, this was an attempt to make losses very painful for the allies.

Zahme Sau

Technically referred to as "controlled object fixed night fighter defense," because the fighter worked with a fighter controller to conduct the intercept, *Zahme Sau* (Tame Boar) tactics resulted from the lack of *Wilde Sau's* decisiveness, and was deemed the most promising due to the continuous fighter control received by the fighters.[101] This tactic used radars (*Erstling-Weitführungsverfahren*), and the *Y-Führung*, or radio reporting to vector fighters to the bomber stream, who then used their AI to locate and attack with more fighters.[102] *Zahme Sau* tactics became very effective, especially with *Lichtenstein SN-2* AI in early 1944.[103]

Day Fighting

For day fighting operations, Germany divided areas under its control into day fighting areas. These areas, the equivalent of a RAF

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[98] von Rohden, *European Essays on the History of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.;*. Aders, *History of the German Night Fighter Force, 1917-1945*, 97-99.

[99] Aders, *History of the German Night Fighter Force, 1917-1945*, 94-97.

[100] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 304-05.

[101] von Rohden, *European Essays on the History of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.;* Oberkommando der Luftwaffe Lw.-Fuehrengsstab Ausb. Abt. Nr. 1410/44 geh, "Reichluft-Verteidigung," Heft 2, 22.

[102] Aders, *History of the German Night Fighter Force, 1917-1945*, 101. and Brown, *A Radar History of World War II: Technical and Military Imperatives*, 319.; "Oberkommando der Luftwaffe Lw.-Fuehrengsstab Ausb. Abt. Nr. 1410/44 geh, "Reichluft-Verteidigung," Heft2, 22.

[103] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 319.

Group, also had subordinate centers equivalent to British sectors. The *Jagdführer* or *Jafü* was in charge of the area.[104] These areas underwent continuous organizational changes throughout the war. Below is an example of the six, day fighting areas in existence in the west around 1943-1944 before the allied invasion.

Name	Approximate Area Covered
Jafü Norwegen	Norway
Jafü Deutsche Bucht (later became Jafü 2)	Denmark and N.W. Germany
Jafü Holland/Ruhrgebiet	Holland, North Rhineland, and part of Belgium
Jafü 2 (later became Jafü 4)	Western Belgium and Pas de Calais
Jafü 3 (later became Jafü 5)	Normandy and Central France
Jafü 4 (later became Jafü Brittany, then absorbed Jafü 2)	Brittany and West French Coast

Table X[105]

Ground Observer Posts

Within each of these areas, *Fluko* posts, part of the *Flugwachkommando* (Observer Corps) reported and plotted aircraft movements to Fluko reporting centers. Between five and six non-commissioned officers and one officer operated each Fluko. One area had approximately 64 observer posts situated 6-10 km apart. Fluko posts used the Zeiss Flakfernrohr (telescopes) to spot aircraft and passed aircraft identification during the day and sound direction information only at night. A "Melderose," or orientation card, provided direction of travel and ensured uniform plotting and tracking. Flukos also estimated height with the terms, very low (50-100 meters), low (100-1500 meters),

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[104] Intelligence Notes, "German Air Defense," p. 1, 1945, Call # 512.6314U V.3, in the USAF Collection, AFHRA, Maxwell AFB AL.

[105] Intelligence Notes, "German Air Defense," pp. 1-2, 1945, Call # 512.6314U V.3, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report, "The German Day Fighter System on the Western Front," HQ Eight Air Force, Office of the Assistant Chief of Staff, A-2, 9 July 1943, Call # 512.6314U V.3, p. 1, in the USAF Collection, AFHRA, Maxwell AFB AL.

medium (1500-3000 meters), and high (3,000-5000 meters). Information from a Fluko reporting center traveled via telephone line to the *Flugmelde Zentrale* (Air Reporting or Air Warning Center).[106]

The *Flugmelde Zentrale*, a plotting and reporting center, compiled and plotted all reports from "radar stations, Fluko observation posts and other Fluko plotting centres, as well as reports from G.A.F. airfields," own aircraft movements, adjacent areas, and civil defense spotters. The plotting center consisted of two parts; the *Dienststelle* (Department) received information and the *Weitergabestelle* (Dissemination Office) disseminated information. The plotting rooms contained telephone receptionists, a plotting table, a start table, plotting map, and a glass-plotting screen. The plotting table, operated by five plotters, had a map with a fighter grid superimposed and from which a red light became active when a report from a post or radar indicated activity. "Positions, altitude, strength, and course of flight of foe and friend were projected on an over dimensional glass screen by means of spotlight and chinagraph pencil." This glass screen separated the *Weitergabestelle* from the rest of the room and only displayed the most important tracks. The *Weitergabestelle* also passed tracks placed on the glass via telephone to other military and civilian authorities. [107]

Each *Jagdfliegerführer (Jafü)* had a fighter control headquarters (*Jagdfliegerführer Jägerleit*) with an operations room or main control room (*Auswertung* and *Fuehrungsraum*). The operations room received, filtered, and plotted information from various sources. Information on friendly track information, known as *Start-und-Sichtmeldungen*, which were essentially aircraft alert status data, and D/F plots on friendlies

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[106] Report, "The Organisation of the German Aircraft Reporting Service in Northern France," Call # 512.6314U V.3, p. 2, in the USAF Collection, AFHRA, Maxwell AFB AL.
[107] von Rohden, *European Contributions to the History of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 18.; Report, "A German Fighter Control, Prisoners Describe the Operations of Jafu 5 Headquarters in France," July 1944, Call # 512.6314U V.3, p. 1, in the USAF Collection, AFHRA, Maxwell AFB AL.

came into the *Peilauswertungen* (Evaluation Section). The *Funkmessaufnahme* (Radio Testing Section) received all incoming Freya and Würzburg radar plots from adjacent centers via telephone and then plotted the data on the vertical glass map in the main control room.[108]

The main control room had three vertical glass maps with data plotted from behind to give the controllers facing these maps an air "picture." To the controllers left stood a weather map, to the right a friendly situation map, and in front the main operational map (10X13 ft). In Jafü 5, that operational map covered an area from London to Le Mans and from Lands End to the Belgium frontier. The fighter controller controlled his aircraft from these displays.[109]

Telephone booths located behind the controller sent information to other relevant organizations. The commander, located on a balcony behind the booths remained connected to other command posts and headquarters via telephone. The commander also attempted to combine the capabilities of searchlights, AAA, and other organizations to maximize the defensive capability. Behind and above the booths was the "Y" Service overlooking the operations board. They called out pertinent information as they received it, but remained physically separated from the rest of the operations room to protect the data coming in from their service.[110]

Higher in the command and control chain was the Central Operational Headquarters (*Zentrale Gefechtsstand*), an underground bunker in Berlin responsible for integrating all Reich air defense. The *Zentrale Gefechtsstand* collected reports, plotted movement, raid

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[108] Report, "A German Fighter Control, Prisoners Describe the Operations of Jafu 5 Headquarters in France," July 1944, Call # 512.6314U V.3, p. 1, in the USAF Collection, AFHRA, Maxwell AFB AL.
[109] von Rohden, *European Contributions to the History of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 17-18.; Report, "A German Fighter Control, Prisoners Describe the Operations of Jafu 5 Headquarters in France," July 1944, Call # 512.6314U V.3, p. 1, in the USAF Collection, AFHRA, Maxwell AFB AL.
[110] "A German Fighter Control, Prisoners Describe the Operations of Jafu 5 Headquarters in France," 2.; von Rohden, *European Contributions to the History of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 17-18.

composition, tracked fighter disposition, passed updated orders or information, and provided a running commentary, called "Jaeger Reportage," to help the leader of the fighter interception forces. Zentrale or the Fighter Divisions transmitted the commentary via high power radio, called the "*Reichs Jaegerwelle*," both during the day and at night. If the enemy jammed the main frequency (*Reichs Jaegerwelle*), then aircraft switched to control from "Anne Marie" stations that now picked up the running commentary. A woman usually provided the running commentary, using code words as necessary to protect communications. The ability to control aircraft over long ranges was feasible due to radio relay stations (on the ground and in the air) across German controlled territory.[111]

Fuehlungshalter

One of the most important parts of the day fighter interception system was the *Fuehlungshalter* (Shadowing aircraft) to track bomber formations. They provided updates to position, weather, escort strength, status of attacks, and movement to the central plotting center. *Fuehlungshalter* aircraft launched after getting information on incoming bomber raids. Once airborne the ARS provided it with updates via radio, but it did not have radio contact with the intercepting fighters. While mostly used during the day, they sometimes operated at night.[112]

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[111] Report, "Daylight Fighter Defence of Germany," June 1944, Call # 512.6314U V.3, pp. 2, 4, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report, "Appendix A, "Wilde Sau"—German Night Fighters," 1945, Call # 512.6314U V.3, p 2-3, in the USAF Collection, AFHRA, Maxwell AFB AL.; "German Day-Fighting in the Defense of the Reich from Sep 15 1943 to the End of the War," Interrogation of Beppo Schmid, p. 3, Call # 512.645G, in the USAF Collection, AFHRA, Maxwell AFB AL.

[112] Report, "Appendix A, "Wilde Sau"—German Night Fighters," 1945, Call # 512.6314U V.3, p 3, in the USAF Collection, AFHRA, Maxwell AFB AL.; General Galland Interview, Part 6, "Air Ministry Weekly Intelligence Summary Issued By Air Ministry A.C.A.A (I)(A.I.I)," No. 318, 8th October, 1945, p. 4, Call # 512.6314U V.2, in the USAF Collection, AFHRA, Maxwell AFB AL.; Report, "Daylight Fighter Defence of Germany," June 1944, Call # 512.6314U V.3, p. 1, in the USAF Collection, AFHRA, Maxwell AFB AL.; Air Defence of Great Britain Intelligence Memorandum, "Notes on the G.A.F Day Fighter System in Western Europe," Call # 512.662, p. 16, in the USAF Collection, AFHRA, Maxwell AFB AL.; Henning, *The High Frequency War: A Survey of German Electronic Development*, 24-25.

Downward Slide

By the fall of 1943, despite success against the allies at Schweinfurt and Regensburg, the German air defense command and control system proved unable to cope with the allied air offensive. Radar and AI jamming, long range allied fighters, inexperienced German fighter crews, bad weather, enemy tactics, and the limited number of *Lichtenstein SN2* AI sets for use in *Zahme Sau* converged to overwhelm Germany.[113] Adjustments made by General Kammhuber attempted to resolve the situation. He directed the initial use of Tame Boar in the *Himmelbett* zones followed by Wild Boar once the battle began while neighboring fighters that did not have bombers in their areas were to enter an adjacent zone using Wild Boar tactics. The reverse was to apply on the bombers homeward journey to maintain a constant attack on the bombers. In August 1943, this method resulted in 200 kills attributed to fighters using the Wild Boar method and only 48 to fighters restricted to the *Himmelbett* areas.[114]

Tactics alone could not solve Germany's air defense problems. General Kammhuber also urgently requested radar, radar personnel, and radio intercept service from the Chief of the Air Force Signal Communications Branch, General Martini.[115] German fighter inferiority was also already evident by December 1943, a situation no amount of radar, tactics, or personnel could overcome.[116] Finally, the Allied invasion in June 1944 and the overrunning of parts of the early warning chain after July 1944 created a gap in the system due to a lack of depth and redundancy. This severely affected the Luftwaffe's command and

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[113] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1*, 63, 66.; Walter Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1a*, 24.
[114] Aders, *History of the German Night Fighter Force, 1917-1945*, 102-04.
[115] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1*, 68.
[116] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1a*, 60.

control capability and by August 1944, the night fighter force was no longer effective.[117]

Technology

Germany did not thoroughly think through what technology it needed for command and control operations. No system existed to guide technological development or to operationalize the technology. Organizationally, the German military did not do a good job of sharing information across the services. The technology it did develop however, was excellent and in several areas, it led the allies, such as in the use of data links to transmit information.

By December 1939, the naval coastal areas had eight Freya radars tied into an early warning system, and contributed to the downing of 12 British bombers on December 18, 1939.[118] In spite of this early success with radar, Germany was slow adopting radar and AI sets. It took until summer 1940 to establish fighter control methods and until 1941-1942 for their effective use. It also took time to order, produce, and integrate radar, IFF, and AI, with heavy use not occurring until 1941-1942.[119] The Luftwaffe procured only three Freyas by 20 October 1939, four by 16 December 1939, seven by 1 January 1940, and nine by February 1940 with all nine assigned to the AWS between Wangeroog and Kleve along the Dutch border. It accepted gaps in coverage along the Dutch border because Germany expected the Allies to respect Dutch neutrality. These nine radars provided overlapping coverage with each Freya providing

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[117] Noble Frankland, *The bombing offensive against Germany; outlines and perspectives* (London: Faber and Faber, 1965), 86.; Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, p 32, in the USAF Collection, AFHRA, Maxwell AFB AL.; von Rohden, *European contributions to the history of World War II, 1939-1945, Air War Book 4: The Battle for Air Supremacy over Germany (German Air Defense) 1939-1945*, 83.; von Rohden, *European Essays on the History of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.*

[118] Hooton, *Eagle in Flames*, 190.

[119] von Rohden, *European Essays on the History of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.*

60-72 miles in coverage.[120] The Luftwaffe had only 22 Freyas when Germany invaded France. The attack on Poland and continued French and British attacks on Germany finally highlighted the threat to Germany from the air and led to an increased need for radar and night fighter squadrons requiring fighter control. By the end of 1940, Germany had only 150 radar sets between the Luftwaffe and Navy and only 250 by the end of 1941.[121] At its peak, Germany had a radar chain from Trondheim, Norway to Biarritz in southern France.[122]

Inexplicably, Germany did not invest much in radio technology for fighter aircraft before the war. There appeared an attitude that communication between aircraft was not necessary. At the beginning of the Battle for Britain, very few aircraft had radios, even night fighting ones. Adolf Galland was not a proponent of aircraft radios, perhaps due to the view that fighter pilots were knights in the sky battling one-on-one against the enemy.[123] The delay in developing and employing radios on a large scale critically hampered Germany's command and control capability.

Germany did not have a centralized organization with scientists to examine the various technical problems until late 1942. By that time, Germany had 1/10th of the British radar research capability. Dr. Hans Plendle, Goering's Plenipotentiary for High Frequency Research, received a Hitler Order to recall 1500 scientists from the Front and attempted to consolidate research since it was spread all over Germany in very small labs. By July 1943, he had 3,000 scientists working for him. In 1941, Martini had already agreed to release 15,000 technicians from the Signal

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[120] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2,* 268-69.

[121] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 86, 100-01, 52.

[122] Intelligence Notes, "German Air Defense," p. 2, 1945, Call # 512.6314U V.3, in the USAF Collection, AFHRA, Maxwell AFB AL.; in the USAF Collection, AFHRA, Maxwell AFB AL.; Report, "The German Day Fighter System on the Western Front," HQ Eight Air Force, Office of the Assistant Chief of Staff, A-2, 9 July 1943, Call # 512.6314U V.3, p. 1, in the USAF Collection, AFHRA, Maxwell AFB AL.

[123] Ulrich Steinhilper and Peter Osborne, *Spitfire on my tail: A view from the other side* (Keston, Bromley, Kent: Independent Books, 1990), 126-129, 197-198.

Corps to industry, but only secured the release of 8,000 due to the need to man front line units. Rivalry and confusion also existed between Milch and Martini regarding who was in charge of radar development, further hampering development.[124]

Despite these handicaps, German ingenuity, engineering prowess, the realities of war, and continued reliance on AAA for the majority of air defense, resulted in more and better radars. German technology reached a very high level leading to an experimental beyond the horizon radar called the *Wurzman* in 1944. It could track aircraft out to 200km and picked up echoes from the moon.[125] Yet, Generals Kammhuber and Martini wanted more, better and longer-range radar, not wonder radars.[126] Notwithstanding these advances and "wonder" radars, by summer 1944, allied changes in technology dominated the German technological cycle.[127]

Radar

The Würzburg became operational in 1940 and immediately teamed with the Freya radar to provide gunlaying, searchlight, height finding, and GCI.[128] When the Würzburg functioned as a GCI radar, information passed from the Freya to the Würzburg for the fighter controller. One Würzburg followed the fighter and a second tracked the bomber. The lack of a PPI prevented the ability to vector a fighter within 1500 feet of a bomber, but nonetheless made it suitable for fighter control.[129]

The Würzburg, considered the best gun-laying radar until 1942-1943 when 10cm radar became the standard, was very similar to the

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[124] Henning, *The High Frequency War: A Survey of German Electronic Development*, 32-33; Price, *Instruments of Darkness*, 131-132, 148.
[125] Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 41, 43-46.
[126] Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 79.
[127] von Rohden, *European Essays on the History of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.*
[128] "German Radar," 6.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 282.
[129] Birkhold, "Enemy Radar."; von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 116.

American SCR-268. Despite the SCR-268's longer range, the Würzburg was more accurate than the SCR-268.[130] Allied aircrews highly respected the German air defense system mainly due to the Würzburg radar set.[131] The final model, the Würzburg D (FuMG 62) reached the front in 1942 and served as both a CGI and AAA radar.[132] Despite serving as the standard AAA radar throughout the war, with approximately 4000 built, it was not the only AAA radar.[133]

The Würzburg's short range led to the creation of FuMG 65 Würzburg-Riese, derived from the Würzburg D, at the end of 1941.[134] This radar was 24 feet across, fixed, used the same scopes as the smaller Würzburg, rotated, had a 40-mile range, was easy to jam, and like all German radars to this point did not have a PPI to facilitate track plotting.[135] Like the Würzburg, it was mobile, but only by rail due to its 18-ton weight. It also required a Freya to feed range data although some units were fitted with Freya search kits to provide it range.[136]

Open competition among the various electronic firms led to the development of the A2 Gerät AAA radar (FuMG 38L Kurfuerst) by Lorenz. It operated with the 88mm gun, was mobile, and had a 12km range. This

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[130] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 80, 82.; Thompson and Harris, *The Signal Corps: The Outcome (Mid-1943 through 1945)*, 9.
[131] "Countermeasures War," 17.
[132] von Renz, *The Development of German Antiaircraft Weapons and Equipment of All Types up to 1945*, 307.; Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 7.
[133] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 282.; Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 7.; von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 158.
[134] Buderi, *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution*, 204.; Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 16.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 283.
[135] "German Radar," 6.; Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 16.; von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 116.; Birkhold, "Enemy Radar."; von Renz, "USAF Historical Studies: No. 194 the Development of German Antiaircraft Weapons and Equipment of All Types up to 1945," 311.; Henning, *The High Frequency War: A Survey of German Electronic Development*, 62.
[136] Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 16.; Henning, *The High Frequency War: A Survey of German Electronic Development*, 62

radar received various improvements throughout the war.[137] The A3 Darmstadt, built by Telefunken, was very precise, remote controlled, had a 10km range, and served as the predecessor to the Mainz and Mannheim.[138] Additional AAA radars such as the FuMG 40L Kurmark AA gun with 25-40km detection and 50km search and the more accurate FuMG 39L Kurpfalz with a 10-25 km range were also developed. The FuMG (FLAK) 40T Mainz (FuMG 63) developed in 1940- 1941, had a 21-mile range, was mobile, and more accurate than the Würzburg but plagued with defects. Only 51 units were developed.[139]

Radar's early success led to a request for better and longer-range radar. Experiments by GEMA in the fall of 1940 led to the Mammut and Wasserman radars that served as the backbone of the German early warning system.[140] These radars were much better than the British Chain Home system.[141] The Germans increased range by increasing the antenna size of the radar and not by increasing the transmitting power.[142]

The FuMg (Flum) 41 G Mammut, a modified Freya, designed to track many aircraft, had a 200 mile range, 180 miles for targets at 20,000 feet and 125 miles at 3,000 feet, but like the Freya had no height finding capability.[143] It entered service in 1942 and served as a fixed

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[137] Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 5-6.

[138] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 115.; Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 6.; von Renz, *The Development of German Antiaircraft Weapons and Equipment of All Types up to 1945*, 305.

[139] Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 5-6, 23.; von Renz, *The Development of German Antiaircraft Weapons and Equipment of All Types up to 1945*, 307, 12.

[140] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 280.; von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 111.

[141] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 194.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 281.

[142] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 111.

[143] War Department, "War Department Technical Manual TM E11-219, Directory of German Radar Equipment, April 1945)" (United States Government Printing Office, Washington: 1945), 38.; Henning, *The High Frequency War: A Survey of German Electronic Development*, 50; Buderi, *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution*, 204.; Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 2.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 281.

early warning radar. The Navy's need for a new long distance air warning radar led to the Mammut-Gustav (FuMG41G (gA), with only four built. Sixteen Mammut-Caesar FuMG41(cF)s were built for the Atlantic Wall, but gaps still existed.[144] Finally, the Mammut-Friedrich FuMG (Flum) 41G (fF), fixed to concrete bunkers and with a 300 km range were built for both the Luftwaffe and the Navy. The British called these radars Hoarding.[145]

Mid-1941 saw the Wasserman L, FuMG (Flum) 41's introduction. It used six Freya antennas, was 37 meters high, had a 200 km range, and was mobile.[146] The Wasserman S FuMG (Flum) 42 was a rotatable Freya with 12 antennas. The Wasserman S, placed in bunkers with very deep foundations had a 47 meter high antenna and labeled the Chimney by the British.[147] The highly accurate Wasserman S detected aircraft at 8000 m at 210 km and very high targets out to 300 km. It rotated mechanically for a 360-degree look.[148] The FuMG 402 I to V or Wasserman M1 to MV, introduced in 1942, had a 300 km range over land targets and 380 km range over water. It served as a long search radar and fighter control radar with the EGON system, described later.[149]

The ever-increasing need for better early warning radar sets led to the development in November 1942 of the Freya-LZ FuMG (Flum) 42G

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[144] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 118, 88.; War Department, "War Department Technical Manual TM E11-219, Directory of German Radar Equipment, April 1945)" (United States Government Printing Office, Washington: 1945), 38.
[145] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 118.; War Department, "War Department Technical Manual TM E11-219, Directory of German Radar Equipment, April 1945)" (United States Government Printing Office, Washington: 1945), 38.; "German Radar," 5.; Report, "Communications and Radar," Headquarters Army Air Forces Intelligence School, Harrisburg, Pennsylvania,1945, Call # 512.6314U V.3, p. 6, in the USAF Collection, AFHRA, Maxwell AFB AL.
[146] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 112, 17. and Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 39.; Henning, *The High Frequency War: A Survey of German Electronic Development*, 62.; Report, "Communications and Radar," Headquarters Army Air Forces Intelligence School, Harrisburg, Pennsylvania,1945, Call # 512.6314U V.3, p. 6, in the USAF Collection, AFHRA, Maxwell AFB AL.
[147] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 112, 17. and "German Radar," 5.
[148] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 280-81. and Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 39.
[149] Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 39. and von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 123.

(fZ), renamed the FuMG 401. It initially had a 200 km range, but improvements increased the range to 400 km. Like the earlier Freya radars, the Freya-LZ still had no altitude capability and transferred its targets to two Würzburg-Riese radar sets, one to track the target, the other to track and control the fighter. Germany produced only 400 Freya-LZs by war's end.[150]

In 1941, the Luftwaffe ordered a panoramic radar with tests finally conducted by mid-1943 and deliveries beginning in April 1944. A panoramic radar provided 360-degree coverage versus the limited directional coverage in previous designs. These tests resulted in a 10 revolution per minute mobile panoramic Freya radar with PPI. Very little resources were available for development, but these tests led to the GCI radar, FuMG Jagdschloss. The Jagdschloss used the first German PPI, had a very wide frequency band to counter enemy jamming, rotated, was fixed, and had a 50nm range for low-level targets and 125 nm range for high altitude targets. The EGON control system, provided the capability to control fighters to 125 miles.[151]

In the summer of 1942, Germany tested the most advanced AAA radar set, the FuMG (FLAK) 41 T Mannheim (FuMG 64). It had remote guidance, used the U37 or a radio to pass information, had a 25-35 km (21 miles) range, was highly technical, mobile, and very accurate in height and azimuth.[152] The Allies saw the Mannheim as a type of small Würzburg with more power.[153] In early 1944, the FuMg 75 Mannheim-Riese (84km range), a larger version of the Mannheim designed to guide missiles entered service.[154]

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[150] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 127-128. and Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 38.

[151] "RCM: Tailored to Fit," *Radar*, no. 8 (20 February 1945): 41. and Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 47. and von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 117, 47-50.

[152] Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 24. and Walter Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1*, 312-13.

[153] "Countermeasures War," *Radar*, no. 6 (15 November 1944): 18.

[154] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1*, 325.

Microwave Radar

Microwave radar was an area of radar technology in which the Germans seriously trailed the Allies throughout the war. GEMA experimented with microwaves but gave them up in 1936 due to repeated failures and did not resume research until 1943.[155] They also attempted to focus on microwaves shorter than 50cm, but manpower shortages slowed their development.[156] At the beginning of the war, Germany had a world-renowned microwave expert in Hans Hollman, although he withdrew from military work due to the nature of the German regime. German corporations continued research into microwaves, but were unable to make any significant breakthroughs. Telefunken stopped microwave research in November 1942 over Luftwaffe Signal Corps General Martini’s objections, due to a shortage of personnel and probably material.[157] Microwave research took an unexpected major leap forward in 1943 after the Germans recovered a British microwave radar, the H2S, in late 1942 from a downed aircraft near Rotterdam. This device provided Germany the knowledge to design and produce microwave radars.[158]

The captured British equipment led to research with super high frequency that was resistant to jamming, resulting in the FuMG 77 Marbach V “Rotterheim,” Germany’s first super high frequency radar. The Marbach used the Mannheim’s stand and dish, the Würzburg’s instruments, and the new high frequency transmitter. Extremely accurate in height and azimuth, it had a 27-30 km range with a 3000-meter target and 35 km range with a 10,000-meter target, but needed height information acquired from other radars.[159] The Egerland system, not tested until 1945, combined the FuMG 74 Kulmbach air

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155 von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 45, 72.

156 Brown, *A Radar History of World War II: Technical and Military Imperatives*, 73, 82.

157 Brown, *A Radar History of World War II: Technical and Military Imperatives*, 310-11.

158 Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1*, 319. and Brown, *A Radar History of World War II: Technical and Military Imperatives*, 317.; von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 45, 72.

159 Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 30, 37. 106.

surveillance panoramic search radar with the FuMG 76 Marbach to be the most effective AAA system. It had a 50 km range, could pass seven tracks per minute, and used the U37 to pass information to AAA. Only two were developed.[160]

By 1 October 1944, allied forces overran over 500 German radar sites in Holland, Belgium and France.[161] By early 1945, there were 65 first-class stations consisting of one or two Wasserman, Mammut or Jagdschloss with two Freyas and one or two Würzburg-Riese and 126 second-class stations with one or two Freyas and one or two Würzburg-Riese.[162]

Air Interception Radar

Germany developed an infrared detection device in summer 1940, but it did not work. That same year, General Kammhuber placed a requirement for AI radar. Deemed very similar to British AI, Germany's first AI radar was a derivative of the Lichtenstein radar altimeter. The Telefunken Lichtenstein B/C or FuGe-202, weighed 110 lbs, used three CRTs (two to give azimuth and elevation, one for range), had a 30-degree search azimuth, and had a range of approximately 8 km or 4.5 miles. The Lichtenstein B/C was ready by fall 1941, but was not mass-produced and sent to tactical units until late 1942. Like the British AI sets, the Lichtenstein was susceptible to ground clutter and maneuvering targets.[163]

The FuGe 202 Lichtenstein B/C AI radar began arriving to front line units by fall 1942 and immediately increased the interception success rate. By July 1943 though, only 80% of front line units had the

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[160] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1*, 320-21. and Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 32.
[161] "Jamming on D-Day: How It Upset Jerry's Radar Front," *Radar*, no. 6 (15 November 1944): 13.
[162] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 20.
[163] Birkhold, "Enemy Radar." and Aders, *History of the German Night Fighter Force, 1917-1945*, 33-34,40. and Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 2*, 305.; War Department, "War Department Technical Manual TM E11-219, Directory of German Radar Equipment, April 1945)" (United States Government Printing Office, Washington: 1945), 14.; and "German Radar," 9.; Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 191.

Lichtenstein B/C.[164] The FuGe 212 Lichtenstein SN-1 arrived in May 1943, was similar to the B/C but heavier, and still had a relatively poor range of approximately 1.5 miles.[165] Operating on the same frequency as the Würzburg, it was easily jammed.[166] The FuGe 220 Lichtenstein SN-2 derived from an antisubmarine radar arrived in June 1943 and became the standard AI for night fighting.[167] It was effective against Window and had a maximum range of 6 km.[168] Although the Lichtenstein FuGe 202, 212, and 220 were the most common AIs, Germany developed a bewildering variety of AIs throughout the war.

IFF

In early 1940, the Luftwaffe became aware of a better IFF from GEMA, called "Erstling" or FuMG25A for the Freya, operating on the same frequency as the Freya and the Würzburg. It took Navy and Luftwaffe cooperation to create this improved IFF.[169] The Luftwaffe received its first operational Erstling, which only responded to the Freya radar, in mid 1942.[170] It could only be set on the ground and not changed in the air, had a 100-125 miles range, could be used as a navigational aid (D/F), and used as a bombing control with two or more Freyas.[171]

Pilots did not like or trust the *Erstling*; they thought they could be

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[164] Aders, *History of the German Night Fighter Force, 1917-1945*, 77-78.
[165] Office of A.C. of S. HQ USAFE, A-2, "The German Air Force Aircraft Warning & Fighter Control System," in *Air Staff Post Hostilities Intelligence Requirements of the German Air Force* (Maxwell AFB, Alabama: Air Force Historical Research Agency, 1 December 1945), 113. and Aders, *History of the German Night Fighter Force, 1917-1945*, 78.
[166] Aders, *History of the German Night Fighter Force, 1917-1945*, 80.
[167] HQ USAFE, "The German Air Force Aircraft Warning & Fighter Control System," 113. and Aders, *History of the German Night Fighter Force, 1917-1945*, 78-79.; Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 191.
[168] Oberkommando der Luftwaffe Lw.-Fuehrengsstab Ausb. Abt. Nr. 1410/44 geh, "Reichluft-Verteidigung," (Freiberg, Germany: Bundesarciv/Militararchiv RL2II/366, September 1944), Heft 2, 15.
[169] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 132-33, 93. and von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 109, 30.
[170] von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 130. and Brown, *A Radar History of World War II: Technical and Military Imperatives*, 132.
[171] War Department, "War Department Technical Manual TM E11-219, Directory of German Radar Equipment, April 1945)" (United States Government Printing Office, Washington: 1945), 2.

tracked by the Allies. Instead, they preferred the Y-Gerat, a beam navigation system now called *Y-Verfahren*. Unlike IFF, *Y-Verfahren* also gave range and provided navigational assistance to the fighter. Fighter aircraft range was determined by transmitting a signal every 20 seconds over a radio in a manner similar to the British pip-squeak system.[172] The arrival of the new Jagdschloss radar in 1944 required a new IFF system, the Neulung FuG-226. This IFF integrated into the new PPI available with the Jagdschloss.[173]

No standard German IFF system existed throughout the war because the Navy and Luftwaffe could not agree on a standard.[174] Perfectos easily jammed and exploited German IFF, causing pilots to turn off their IFF. This made controlling extremely difficult. Germany's lack of aircraft to aircraft IFF resulted in a directive to not attack two engine planes at night.[175] Overall, German IFF was not effective in helping controllers determine friend or foe.[176]

Passive Systems

Germany augmented its fighter control and air defense system with various passive systems and services, which could not be jammed.[177] The *Flensburg* device, integrated into the fighter AI set, exploited the bomber's tail warning radar called Monica. Germany also countered allied jamming efforts by increasing frequency spectrum use, introducing anti-jam circuits, and developing computer systems to handle multiple Würzburgs

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[172] Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, p 47, in the USAF Collection, AFHRA, Maxwell AFB AL.; Brown, *A Radar History of World War II: Technical and Military Imperatives*, 284.
[173] Henning, *The High Frequency War: A Survey of German Electronic Development*, 89.
[174] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 132. and von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 79.
[175] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 133-34, 319.
[176] "German Day-Fighting in the Defense of the Reich from Sep 15 1943 to the End of the War," Interrogation of Beppo Schmid, p. 1, Call # 512.645G, in the USAF Collection, AFHRA, Maxwell AFB AL.
[177] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 284, 319.; Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 278.

to direct multiple AAA batteries.[178] The British attempted voice jamming, but this had a limited affect when German fighters had the *Naxos-Z* and *Korfu* system installed, picking up British H2S radar emissions. The only counter tactics involved waiting until the last possible moment to turn on the equipment.[179]

VHF D/F System

Aware of the role of the British fighter control system, Germany endeavored to create a VHF D/F capability under the responsibility of the Signal Corps for use in day fighter operations. Slow development led front line German fighter units to approach German industry for such a system, effectively bypassing the Signal Corps, resulting in a functioning VHF D/F system by the summer of 1941. This system functioned in the same manner as the Allied system.[180]

Other Equipment

Unlike the Allies, the Germans relied extensively on other systems besides radar, AI, and IFF to enhance their fighter control capability. These included extensive anti-jamming devices, data link systems, and various control systems reliant on radio frequency. As with many other German technologies, these systems and concepts served as the basis for American post-war technological development.

On 27/28 February 1942, a British commando raid near Le Havre captured a Würzburg A radar. The British exploited the knowledge from the captured Würzburg to create chaff, called window, to jam the radar. Before the British exploited their knowledge, the Germans, completely aware of the implications of the British raid, made a decision in March to give the Würzburg multiple frequencies under a project called Wismar.[181]

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178 "RCM: Tailored to Fit," *Radar*, no. 8 (20 February 1945): 39.
179 Brown, *A Radar History of World War II: Technical and Military Imperatives*, 319. and Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 23.
180 HQ USAFE, "The German Air Force Aircraft Warning & Fighter Control System," 38.
181 von Kroge, *GEMA: Birthplace of German Radar and Sonar*, 123-24. and Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 29-30. and Grabmann, *German Air Force Air Defense*

Shortly thereafter, on 24/25 July 1943, the British attacked Hamburg using Window successfully against the Würzburg and Lichtenstein, while using electronic jamming against the Freya as chaff did not exist yet for use against it. The British attack used chaff and electronic jamming to effectively shut down German radars. German AAA and fighters could not handle the large number of concentrated bomber streams without the information provided by the radars and the fighter controllers. This resulted in very light British losses and devastating damage to Hamburg.[182]

The Germans countered chaff and electronic jamming not only by using multiple frequencies but also by developing systems to help the fighter controller see through the jamming. In succession, they developed the Würzlaus system in August 1943 to allow chaff to be broken out from real traffic, and the K- Laus at the end of 1944, a better system, in conjunction with the Würzlaus to get better results.[183] The Würzburg-Riese and Mannheim radars used these systems.[184] By May 1944, the Allies developed chaff to exploit the Freya, Wasserman, Mammut and Jagdschloss radars with the Germans quickly countering with the Freya-Laus for the Freya and the Wasserfloh for the Wasserman and Mammut. The Jagdschloss had no counter system before the end of the war.[185]

Events in September 1943 testify to Window's success against German radar, AI, UHF radios, and Himmelbett tactics. The 22/23 September 1943 raid over Hannover involved between 300-400 bombers

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Operations 1933-1945 Vol 1, 314-15. and Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 30.

[182] von Rohden, *European Contributions to the History of World War II, 1939-1945; The War in the Air. Reich Air Defense, 1939-1945; A Strategic-Tactical Survey*. and Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 30. and Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 63.

[183] Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 30.

[184] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1*, 316. and Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 30.

[185] Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 30.

and 221 fighters, and resulted in the loss of 19 bombers and two fighters. The next night, an attack against Mannheim-Darmstadt with the same number of bombers and fighters resulted in only 30 RAF bombers and 10 fighters destroyed.[186]

German technical knowledge improved the chances of success with the development of passive detection systems such as the FuG227 Flensburg-Hale with 124 miles detection, the FuG350Z Naxos Z with a 31-mile detection range, and the FuG221a Rosendaal-Halbe.[187] These systems exploited the electronic emissions from bombers, allowing German fighters to assist the fighter control system by getting an electronic bearing on their location from a bomber's electronic emissions. Foreshadowing the widespread use of data links today, the Germans also developed exceptional remote control systems to control radars, searchlights, and aircraft. The EAG62 "Emil" D-Zusatz, attached to Wurzburg Ds after 1942, gave it improved ranging accuracy, maintained calibration, operated easier, and could feed data directly to the *Übertragungsgerät*. Developed in 1942 and operational in 1944, the FuMg 68 Ansbach could operate six or more batteries of AAA, was mobile, and had a 35 km range, with search capability to 60-65 km. Few were produced despite its exceptional capability to assist in integrating fighter control and AAA action.[188]

The FuG 135 (Uhu) Owl, a ground based, data transmission device, attempted to provide a precise control method. The fighter controller fed track information into the FuG 135 and the device sent vectors to a display in the cockpit. It did not work will well, and therefore abandoned in late 1941.[189] Another device, known as Askania, took data from the Wurzbürg-Riese, plotted it onto the Seeburg Table, and

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[186] Grabmann, *German Air Force Air Defense Operations 1933-1945 Vol 1*, 10, 12-15, 65.
[187] Aders, *History of the German Night Fighter Force, 1917-1945*, 126.
[188] Muller, *Ground Radar Systems of the German Luftwaffe to 1945*, 15, 28.
[189] Aders, *History of the German Night Fighter Force, 1917-1945*, 38-39.; Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 188.

transmitted the data directly to the fighter reducing intercept errors and time lag. The Askania replaced the six people previously needed to plot and transmit information to the fighter.[190]

A similar system, the Uhu-2, introduced in 1943, was a data system that eliminated voice communications. It took data from the radar and Seeburg Table and sent it to the fighter, similar in fashion to the Askania. The Uhu-2, unlike the Askania, controlled the aircraft on autopilot. The system was very easy to use and not susceptible to jamming. It could only conduct one intercept at a time because of the radar tracking capabilities of the Würzburg-Riese, but the controller could conduct two intercepts with two Würzburg-Riese radars by using each one for the target and the Uhu-2 or Benito control system (explained below) to control the fighter. A manual technique developed whereby the fighter controller conducted repetitive intercepts as quickly as possible, once the fighter called visual with the enemy, but this required exceptionally good controllers. The Luftwaffe discontinued the Uhu-2's use after General Kammhuber's dismissal on 13 September 1943 because many within the leadership chain did not realize the value of the system.[191]

The *Erstling-Weitführung* or EGON (Erstling-Gemse-Offensive-Navigation), fighter control system was originally a bomber guidance device. The EGON used a Freya radar with Gemse IFF. The ground control station sent a signal to and received a signal from the FuG 25a Erstling IFF. Each aircraft returned a steady radar echo to the Freya and the IFF returned a beat coded with letters. Therefore, each IFF beat was unique, giving the fighter controller the ability to distinguish many blips on the display screen. The EGON system allowed only 70 Freya-Gemsa's

[190] Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 71.
[191] Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 72, 75-76, 199.

to cover all of Germany.[192] The system provided a range of 200 km at medium altitude. Only the lead aircraft operated the system, although different codes allowed multiple formations to use the system simultaneously.[193] A single system could control 4-5 aircraft. It became the Luftwaffe standard technical means by 1944.[194]

The Luftwaffe also adopted the Y-Führung or Benito system method of fighter control in July 1942. This system used a radio transmitter and receivers to send messages between the ground controller and the aircraft in order to locate the friendly fighter's position.[195] It worked via instructions sent over radio to the aircraft and retransmitted to the ground for interpretation. The ground station also determined the range and position by calculating the bearing of the signal. The system detected position by measuring the "difference in course time of the carrier modulation wave picked up by the receiver after it had been sent out from the transmitter and reflected back to the target."[196]

The Y-Führung system, used for both day and night fighter control, increased the number of friendly aircraft a fighter controller could control. The number of Y-Systems available to units limited the number of aircraft controlled. A single system could control up to three groups of fighters by using different codes. Only the lead plane in a formation had the system on. The data fed into the Seeburg Table to complement the data received on enemy tracks from the Freya and Würzburg-Riese.[197]

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[192] Henning, *The High Frequency War: A Survey of German Electronic Development*, 73.; Aders, *History of the German Night Fighter Force, 1917-1945*, 76, 127.
[193] Oberkommando der Luftwaffe Lw.-Fuehrengsstab Ausb. Abt. Nr. 1410/44 geh, "Reichluft-Verteidigung," Heft 2, 24-25.
[194] Henning, *The High Frequency War: A Survey of German Electronic Development*, 24.
[195] Aders, *History of the German Night Fighter Force, 1917-1945*, 76-77.
[196] Kammhuber, *Problems in the Conduct of a Day and Night Defensive Air War*, 194.; Henning, *The High Frequency War: A Survey of German Electronic Development*, 72.
[197] Oberkommando der Luftwaffe Lw.-Fuehrengsstab Ausb. Abt. Nr. 1410/44 geh, "Reichluft-Verteidigung," Heft 2, 24, 27.; Henning, *The High Frequency War: A Survey of German Electronic Development*, 24, 45.

The final technical control method was the UKW-Peil-Fuhrungs. This D/F system transmitted a second signal on the FuG 16 radio and required three ground stations to ensure accuracy. At 100 km, it could pinpoint the location of a fighter to within a 1000-meter box. It had a useful range of 150 km. Voice instructions could be given over the system.[198]

Finally, late in the war, Germany developed a very advanced and excellent control system called Bernhardine for use during night fighting, but German industrial capacity and its high cost precluded its widespread use. It served as a navigational aid and could receive running commentary in the form of teletext messages to the fighter aircraft versus voice commands.[199]

One of the most critical elements of a successful fighter control system is a unified air picture on a single scope. The lack of a PPI until the Jagdschloss made the fighter control process labor intensive, time consuming, and difficult. This cumbersome hand plotting method mirrored the system used by the British and Americans before PPI.[200] Each fighter sortie required 140 personnel to run all aspects of air defense.[201]

Conclusion

Despite Germany entering the war with an underdeveloped, almost non-existent command and control system for air defense, the official British historical assessment is that the German system adapted and did rather well until June 1944.[202] A look at the numbers explains why.

Fighter Command and Bomber Command day losses in 1941 were 2% and 7.68% respectively, with overall bomber losses at 2.5% for day

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[198] Oberkommando der Luftwaffe Lw.-Fuehrengsstab Ausb. Abt. Nr. 1410/44 geh, "Reichluft-Verteidigung," Heft 2, 25.; Henning, *The High Frequency War: A Survey of German Electronic Development*, 72.
[199] Henning, *The High Frequency War: A Survey of German Electronic Development*, 48.
[200] "PPI & Microwave," *Radar*, no. 2 (May 1944): 10.
[201] Brown, *A Radar History of World War II: Technical and Military Imperatives*, 204.
[202] Great Britain, *The Rise and Fall of the German Air Force, 1933-1945*, 283.

and night operations, while Germany's were less than 1%. Bomber Command night losses were extremely low. By 1942, the German system was a "real threat to the operations of the Royal Air Force Bomber Command" inflicting a 4% loss rate to Bomber Command. In 1943, it decreased to 3.6%,[203] while causing prohibitive losses to the Americans over Schweinfurt on 14 October 1943, destroying 60, and damaging 138 bombers to a German loss of 35 fighters. Germany's command and control system and fighter force had indeed become very effective.[204]

By early 1944, the German system was effective enough to cause 8-9% loss rates on some nights and checked British bombing efforts until the invasion in June 1944. Bomber Command had to stop bombing deep inside Germany to remain viable as a force and their mission shifted to supporting the invasion preparation.[205]

This success is remarkable considering German deficiencies in the areas of organization and technology. Organizationally, Germany did not centralize its command and control processes for air defense until 1944 despite attempts to do so as early as 1941. It made too many distinctions regarding offensive and defensive use, day and night fighters, and allowed geographic division to hamper defensive efforts. It over focused on offensive action, did not foresee a protracted war, and relied primarily on AAA for defense, failing to implement a combined weapons approach to increase effectiveness. The Nazi system of empire building and dividing responsibility to deprive any one individual from having too much power contributed to fragmented efforts. In a post hostilities report, General Schmid stated, "In my opinion the organization of the Reich Defense is one of the greatest mistakes made by the High Command and the

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[203] Great Britain, *The Rise and Fall of the German Air Force, 1933-1945*, 185, 275. 278.; Price, *Instruments of Darkness,* 70.; Hooton, *Eagle in Flames*, 113.
[204] Frankland, *The Bombing Offensive Against Germany; Outlines and Perspectives*, 77.; von Rohden, *European Essays on the History of World War II, 1939-1945, Book 3: The War in the Air. Reich Air Defense 1939-1945: A Strategical-Tactical Survey.*
[205] Frankland, *The Bombing Offensive Against Germany; Outlines and Perspectives*, 72.; Great Britain, *The Rise and fall of the German Air Force, 1933-1945*, 279.

GAF."[206]

Technologically, it did not have an organization or plan to integrate existing and emerging technologies for command and control. Over time, Germany added vast amounts of varied equipment. This prevented standardization, affected training and adaption, an inability to move personnel, and made the command and control process very manpower intensive as system upon system was grafted on. The myriad of systems also bogged production capability. As it did organizationally, interdepartmental fighting and intrigue stunted technological development and processes.

These organizational and technological problems hampered the processes used. By the end of the war, Germany had a system, but one that could not handle large data or control multiple aircraft in the same way the allies did. Organizational changes in 1944 streamlined the command and control process, but appeared too late. German technological development was reactive versus proactive. The allies were always one step ahead. Better and esoteric capability became a panacea. Germany did not realize until too late that command and control is a system, not a single weapon or capability. Finally, Germany never focused on technology or processes to manage large amounts of data and control aircraft in a manner flexible enough to match the allies. To counter the allied superior numbers it needed to be able to control more aircraft simultaneously, to concentrate its efforts, and make offensive action deadly for the allies.

Germany may have been able to overcome its organizational, process, and technologically deficiencies if it had started earlier. Before the war, Germany had no systematic long-range strategic plan regarding command and control. Success came through changes in the crucible of

[206] Post-Hostilities Report of General Joseph Schmid, "Night Fighter Operations," Call # 512.645-5, p 59, in the USAF Collection, AFHRA, Maxwell AFB AL.

war, but it was too little, too late.

Section Summary

Organization

The start of war found each nation focused on different aspects of command and control that reflected their particular doctrines and strategic circumstances. The UK started with a strong air-to-air command and control system and an almost non-existent air-to-ground command and control system. Organizationally, the RAF and British Army fought doctrinal battles over who controlled air power. While battlefield experience validated the concept of centralized control, decentralized execution under an airman, it took a political directive from Churchill to end the dispute. Once developed and refined, the British air-to-ground approach served as the model American airmen looked at to confirm its notions of centralized control. The command and control processes of the two were otherwise extremely similar. As with the Americans, the British system was well rounded, efficient, and effective.

The US entered the war in 1941 with two extra years of preparation, the opportunity to observe air operations such as the Battle of Britain, and use British instructors and syllabi at its schools. During its first action in North Africa, US command and control doctrine and concepts proved sound, but suffered in the execution. Army desire for the control of air power overrode the concepts of FM 31-35 regarding centralized airpower. Understandably, every commander wanted air cover. Political intervention fixed this as it had for the British. By the end of the war, while defensive measures still existed, the allied command and control system was almost seamless in its conduct of air-to-air, air-to-ground, offensive, or defensive operations. The allies also much more rapidly arrived at an organizational state of centralized control and decentralized execution much quicker than did the Germans.

Conversely, Germany began the war with a robust air-to-ground command and control system and a relatively weak air-to-air command and control system, one based on 'eyes and ears' and not on radar. Germany took until 1944 to finally centralize its air defense for air-to-air operations, but based on resources, reached that point in 1942 on the eastern front for air-to ground operations. Nazi culture also hampered organizational effectiveness by creating fiefdoms within the Luftwaffe. Finally, unlike the Allies, Germany never created a command and control system in which defense, offense, air-to-air, and air-to-ground operations functioned as one system. The major reason was that Germany was defending the Reich and separately conducting air-to-ground operations far from the Reich. By the time the allies landed on the continent, their homeland was not threatened, thus they were able to use more fighter aircraft for offensive operations and blend air-to-air and air-to-ground operations. Limited fighter aircraft did not permit Germany to do so. It had to balance air defense against the allies in the west with supporting Army operations in the east.

Processes

The strengths and weaknesses of each nation's processes mirrored its strengths and weaknesses regarding organization. Organizational structure and centralized control resulted in processes that were more effective. The processes that evolved during the war followed the same basic concept of gathering data, analyzing it, and then using it to maximize force employment. The US and UK's more centrally controlled and decentralized command and control system received information and sent it to the appropriate organizations for execution. The system employed by the TACs in northern Europe illustrates how this concept worked even with an air control system that branched out with various subcomponents of the FCC. Strategic air forces conducted operations in accordance with the overall plan of the Supreme Commander, conducting strategic missions into Germany and integrating into tactical operations. Tactical fighters were also able to support strategic operations. The integration of intelligence was also smooth.

Both UK and US air forces had doctrinal disputes with their ground forces over who controlled air power. The constant conflict between the air forces and the army forced the two services to find a solution. This led to compromise, better ideas, understanding, and in the end execution, even if it took political direction. Centralized air power with air force, ground, and naval forces working together created not only efficiency, but also effectiveness. Aircraft were applied to where it had the most impact and despite the large number of aircraft available, there was never enough airpower to do all the missions all commanders' want accomplished.

In contrast, the fragmented German air defense system made it more difficult to counter allied attacks. The fragmentation of air warning and the ability of leaders to prevent leaders from other organizations from obtaining information proved harmful. The German air-to-ground system worked well and was effective, but resources made it impossible to support all ground commander needs or to develop into the robust command and control system, as did the allies. Germany's air-to-ground system did not develop the organizational structure or process of the TACs/2 TAF probably due to the lack of resources. The Luftwaffe simply did not have enough aircraft to cover a wide front and provide fighters in large numbers to both fronts. In the east, it met a mainly tactical Soviet air force while in the west it met a mainly strategic air force until June 1944. It made sense that the Luftwaffe, with its limited fighters never had the ability to produce the offensive air-to-air capability in the east to integrate with its air-to-ground system. Limited and dwindling Army resources drove the Luftwaffe into a cycle of never ending support, as airpower became a means to overcome diminishing German strength on the ground.

Technology

The UK had an early lead in the development and application of technology. The US was not far behind and as the two nations interacted and exchanged data, the creation of technically better and more specialized equipment accelerated. The Allies parlayed microwave technology into multiple radar systems, giving them better information. Just as critically, the development of the PPI allowed for much more precise, real-time control, and the ability for multiple controllers to control multiple aircraft simultaneously. Technology facilitated the decentralization of control to units such as FDPs and CCUs. This provided more accurate data and increased reaction time. The allies were able to take technology, see an operational need, and either create a system or modify one to increase battlefield performance. While the equipment developed was very good, the allies also focused on getting something to the field.

Germany began the war behind the allies in terms of microwave technology and PPI and in the quantity of technical equipment (radar, AI, and IFF) available to its forces. Their radars were of high quality, but the lack of microwave radar and PPI deprived Germany of more accurate radar information and the ability for controllers to control more aircraft. It also made the control processes more cumbersome and, time and labor intensive. This deficiency limited the number of allied bombers that fighters could attack and thus, bomber compression tactics prevented German fighters from affecting allied operations even more so than they already did. This proved a liability and the allies overwhelmed the German system. While Germany did produce other very advanced radars towards the end of the war, it developed them too late and did not do a good job integrating the new technology into the existing command and control system. Finally, Germany did not have the industrial capacity to build a myriad of systems and still positively affect operations. For example, the EGON and Benito control system not only required different production lines, it also impacted the training of maintainers, technicians, controllers and pilots. Making a decision to adopt a single system could have resulted in more systems, streamlined training, and improved the flexibility in terms of day and night fighters flexibility and what airbases aircraft recovered to. Overall, Germany did not do a good job envisioning how technology outside the aircraft itself could enhance operations; too many leaders appeared focus on flying and their vision of dueling knights in the sky.

By the end of the war, it was clear that command and control of air forces was a critical function all air forces had to have to conduct successful operations, whether offensively or defensively. Command and control attempted to make air warfare manageable. To do so required the careful and purposeful creation of organization, processes, and technology. Effective command and control systems had these three legs of the stool well thought out and implemented.

Chapter 8

Conclusion

Command and control is air power's sinew. Without it, air power is less effective and those with it have an advantage over those without it. This study has shown how the three dominant air power nations of the WWII European theater followed very different command and control developmental paths. Nevertheless, by the end of WWII, Germany, the UK, and the US fielded effective command and control systems. These systems came about for various reasons, at different times, and with varying degrees of integration. Despite these differences, the basic idea of a command and control system, whether for air-to-air (air defense) or air-to-ground, was to allow a commander to make a decision to support combat operations, and then see to the implementation of that decision. Organizationally, the command and control of air power tended toward centralizing control. At its core, each country designed processes and technologies to gather information for a commander to make a decision and then disseminate it for action to subordinate units. Differences between the three nations centered on when each nation created their system, implementation, and the specifics of the organizational structures, processes, and technologies. Broadly, organization, processes, and technology were similar. This study has covered those specific details. Asking the question, "did they have a 'need, some need, or no need' for either an air-to-air or air-to-ground command and control system" will help answer the "when and why?"

Before WWI, no nation had the experience to extrapolate the need for a command and control system, other than the basic concept that all military forces require some system of command and control. Most nations had conceived of basic aerial observation tasks and artillery spotting aircraft. These aircraft simply gathered information for a commander, but no formal system existed to command and control airpower. Once war began, the need emerged for a system to command and control ("orchestrate") airpower to make the most effective use of limited air resources.

During WWI, the UK and Germany needed to build an air defense command and control system for both the battlefield and to defend the homeland. Eventually each needed a specific command and control system to direct aircraft against ground targets in support of ground troops. For both nations, war was the impetus for creating a command and control system. On account of its late entry into WWI, and resulting lack of experience and technology, the US adopted the British system. Remarkably, despite following slightly different paths, all three nations ended the war with extremely similar organizational processes and technology. The simplicity of the processes and technology led to a striking commonality of ideas and practice.

In the years following the Armistice, it was clear that the UK still required an air-to-air command and control system. First, experience during WWI made it clear, to politicians and the public, that the UK was no longer safe from direct enemy attacks, especially from the air. While the British developed an effective command and control system on the continent, the attacks on London left a lasting mark on both the population and politicians. The attacks brought the stuff of prewar fiction and fantasy to life. Airpower's growing capability coupled with popular literature added to the public fear of its destructive power. London became a target less than 15 years after the airplane's invention and the public understandably extrapolated those results into the future. The next war would surely bring about greater destruction.

By the early 1920s, a broad group of stakeholders (politicians and the RAF) realized the UK needed a system of home defense and began the process of investing in forces and developing the infrastructure for a defensive system that evolved into a command and control system. Over time, politicians across the political spectrum reacted to the realities of the strategic and fiscal environment. When the chance of war seemed remote, the government spent little on defense. As the international environment changed, the British government began to hedge and slowly resumed spending, finally focusing on defensive systems to ensure national survival.

Second, British history and geography lent itself to developing an air defense command and control system. Historically, the British navy played the central role in defending the nation by being stronger than any two adversaries, attacking the enemy at a distance (their homeland), and preventing enemy forces from landing (the last successful invasion occurred in 1688). Using aircraft to defend England from not only air attack, but also invasion, was a natural extension of the traditional role assumed by the Royal Navy. Fittingly, the RNAS first assumed responsibility for air defense beginning in 1914, rather than the RFC.

The idea that airpower could defend the UK by deterring an enemy with the threat of bombardment permeated military thinking. The British Cabinet, accepting the viewpoint expressed in the Inskip Report, thought otherwise and viewed defensive capability as the best option given the geography, fiscal environment, and (after the mid-1930s) awareness of the capability of radar. The UK's small size made developing a defensive command and control system somewhat easier. Its location also meant there existed only a few avenues of approach from potential adversaries. Conversely, while British geography provided some protection, the closeness of London to the continent made the city vulnerable. With bomber aircraft speed approaching that of pursuit aircraft by the late 1920s, the UK realized it had a limited amount of time to detect and intercept incoming enemy aircraft. Airpower almost made London part of the continent, as Luftwaffe chief Hermann Goering famously noted, "England's no island any more." The UK had a pressing reason to find a solution.

Third, limited resources during the interwar period influenced the need for a command and control system. Airpower had already proven effective in the colonies despite relatively small numbers, shaping political decision-making. The Inskip Report expressed the opinion that defensive operations were a better value because fighters cost much less than bombers. This meant more fighters for the same cost as fewer bombers. Finally, the high cost of maintaining a large standing Army did not appeal to politicians, especially in the economic environment of the late 1920s and 1930s.

Fourth, formal technological developmental processes led to breakthroughs and a systematic application of technology to solve problems. Scientists, not military men, looked at the air defense problem holistically and recommended using science to solve the problem. For its part, the Air Ministry was very open to science and once a solution seemed feasible, the military and government threw their full weight of support into developing radar.

Finally, a resurgent and more belligerent Germany spurred the Neville Chamberlain government to implement the Inskip Report’s recommendations, engage in a hedging strategy, and forced a doubtful RAF to improve its defensive capability over continuing to expand its offensive capability. Not personally invested in the counteroffensive doctrine, Chamberlain and Inskip were more willing to change strategies, ultimately gravitating towards one grounded in economic conditions and one less theoretical and more realistic. After all, if the RAF thought they could get through with their bombers, then why could the enemy not do the same? The RAF’s strong belief in the efficacy of the bomber should have led the RAF to focus more than it did on air defense before forced to do so. The RAF’s belief in the bomber’s efficacy however was not unique as bomber advocates in the US strongly held the same belief. With a policy formulated however, the RAF moved forward very effectively, however reluctantly, to implement the policy directed by its political leadership.

The developmental path to Britain's famous command and control system was evolutionary, not revolutionary. Most importantly, the UK had a foundational system that worked during WWI and revived in the early 1920s. Improvements to organization, processes, and technology occurred slowly. Despite a strong belief in the counteroffensive doctrine, the RAF continuously attempted to solve the intercept problem, conducted exercises, experimented with technology (first sound mirrors, then radar), and built the organizational structure to support these efforts. By 1938, through a combination of assessing Germany's strength and perceived intentions, British production capabilities, and with the knowledge of the system Fighter Command was building, the Inskip Defense Review saw what the RAF could not see. They saw that fighters under the direction of a command and control system provided the best chance of surviving an attack and then counter attacking. Radar under a command and control system made the defense dominant over the offense.

Ironically, the same factors pushing the RAF towards developing a robust integrated air defense system worked against the same force developing an air-ground command and control system until the outbreak of WWII. First, most authorities believed the next war lay in the distant future. Without a threat, there simply was no impetus for the services to cooperate and overcome doctrinal differences. Second, budgetary constraints focused limited resources on the much more favored counterforce doctrine. Despite a lack of any compelling evidence, the RAF believed the counterforce doctrine had a deterrent effect and thus made a greater impact on British security. Third, a small British Army was more concerned with regimental soldiering than with developing a cooperative air-to-ground system. Unlike the development of an air-to-air command and control system, the development of the UK's air-to-ground command and control system occurred due to an immediate need to conduct combat operations, rather than preplanned systematic development. It developed in the crucible of war and only after costly failures.

For several reasons, the US did not need to establish a command and control system for air power, either air-to-air or air-to-ground. First, geography placed the US outside the operating radius of any nation with an Air Force. No nation within striking distance existed; therefore, the US never worried about the possibility of attack. Various post-WWI boards confirmed this assessment and made it formal policy. Naval bombardment or an invasion was possible, but also highly unlikely.

Second, with limited fiscal resources the Air Corps chose to focus on bombardment aircraft and their immediate supporting technology, not technologies related to command and control. Specifically, the Air Corps focused on developing equipment and techniques to implement their evolving strategic bombing doctrine. Unconsciously mirroring the UK, the Air Corps neglected fighter aircraft development until the late 1930s, when they could no longer ignore the evidence from other nations that fighter performance had begun outpacing bomber performance. The evidence also suggested that fighters operating with an aircraft warning service made the cost of bomber operations prohibitive in the absence of fighter escort. Minimal investment had kept the fighter industry alive. Whether the Air Corps would have spent more money on fighters or command and control if given more resources is unlikely. Bombardment defined the Air Corps and it is highly probable that more money would have meant more bombers.

Third, while the Air Corps used defense (broadly defined) as a reason for purchasing bombardment aircraft, the Coast Artillery Corps pushed command and control development. Almost all technological funding for a defensive command and control system came from the Coast Artillery Corps. It invested in concepts like an intelligence network, and technologies, such as radar, to assist searchlights and AAA in finding and tracking enemy aircraft. Voices within the Air Corps called for the development of a command and control system, but bomber advocates drowned them out. While there is no clear evidence suggesting so, there is also the real possibility that bomber advocates did not want a command and control system because they understood such a system weakened their claims of the bomber's superiority and ability to get through. Bomber advocates always applied a 100% success criterion to defensive pursuit during exercises and maneuvers. To these advocates, a single bomber getting through proved the command and control system's ineffectiveness. Bomber advocates simply dismissed evidence that even poor performing pursuit with a command and control system could adversely affect bombardment aircraft. Bomber advocates exhibited cognitive consistency, avoiding, and dismissing data not consistent with their viewpoint. Nonetheless, the development of command and control in the US was as in the UK evolutionary rather than revolutionary, and the efforts of the Coast Artillery Corps and minority voices in the Air Corps set the foundation for a command and control system.

The international environment affected when and why the US created a command and control system. Improving fighter performance, the availability of more money, and evidence from the British experience meant there was now a need to develop a command and control system. For the US, this came from within the Air Corps and Arnold's suggestion for the development of an Air Defense Command. A cynic could argue that by 1939, Arnold and the Air Corps viewed a formal air defense system as a move for not only more money, but greater independence from the Army. In the face of a real threat, this claim of a unique mission capability had credibility. The RAF had also used the argument after WWI to maintain its independence. It took the reality of war (Pearl Harbor) to solidify the need for a command and control system.

For almost the same reasons, the US did not need and therefore neglected developing an air-to-ground system until war appeared probable. The threat of an invasion seemed remote as geography separated the US from any of the great powers. Second, as with air defense, fiscal constraints limited the number and types of aircraft it produced. Third, even though its primary mission was to support the army, airmen were much more interested in strategic bombing doctrine and without outside pressure it concentrated on what its leaders wanted to emphasize. Finally, with a small land army oriented to defending the US, the idea of a command and control system for air to ground operations simply did not have priority. Americans did not envision close cooperation between air and ground troops to the level requiring a separate command and control system. Even by 1942, the Army and AAF viewed air-ground cooperation as complex and difficult, focusing on pre-planned support and avoiding impromptu support.

Germany, a defeated, disgraced, and weakened power in 1918, certainly had a need for a defensive command and control system. After WWI, Germany feared a Polish invasion in the east, yet treaty prohibitions prevented Germany from having aircraft or an air force. Germany employed an "eyes and ears" warning system throughout the country, but focused these efforts most heavily in the east as a precaution against Polish invasion. Germany also focused on integrating its warning system into its civil defense programs. By the 1930s, the Polish threat had abated and even though France was strong, Germany did not fear French aggression. There was therefore no overwhelming threat to force the development of better detection devices or processes, yet Germany built the most robust air defense system in terms of the number of AAA pieces in Europe to hedge against the other powers. Germany was relatively satisfied with the existing command and control system, but continued to conduct air defense exercises and improve its early warning network. Unlike the British embracing technology, the

Luftwaffe did not purposefully look for better technology. The German Navy developed the first radars, but organizational culture, both military and Nazi, prevented the sharing of the knowledge. Mirroring the UK and US, Germany's command and control development was evolutionary rather than revolutionary until 1941 when the influx of radar forced major changes to the command and control system almost overnight.

German doctrine focused on mobile operations seeking a battle of annihilation to quickly end a war. Its geographic location and potential of fighting on multiple fronts had always driven Germany to find quick ends to wars. With the idea that wars were to be short, there was no need to build an elaborate and in-depth air defense system; warning and AAA integration would be sufficient. The strains of rapidly building the Luftwaffe forced Germany to make command and control less of a priority relative to other functions.

The Luftwaffe's offensive doctrine also meant it viewed aircraft as tools for offensive employment, not defensive. The enemy would not be able to attack the homeland if its air force was defeated at its bases. Fighter pilots did not like conducting defensive operations and balked at having to do so under the command of an air defense officer that was usually a non-pilot. This thinking stymied the development of a command and control system beyond the eyes and ears system it had at the start of WWII. War once again triggered massive change.

Germany developed an air-to-ground system for two reasons; doctrine and geography. Doctrinally, Germany sought a decisive battle to destroy the enemy's military forces. This naturally led to a focus on ground support, although not to the exclusion of all else. The Luftwaffe believed air superiority to be a prerequisite and believed in strategic bombing to destroy the enemy air force and attack a nation's "centers of national resistance." However, while the Luftwaffe was an independent service, it drew its initial cadre of officers from the Army, so it naturally aligned more with supporting ground operations. Germany also had a rich history of combined arms warfare leading to a greater tendency to cooperate. After WWI, the German military focused on increasing battlefield mobility, and airpower was one way to help achieve it. This requirement led to the development of an air-to-ground command and control system in the Spanish Civil War and continued refinement thereafter. Germany's air-to-ground command and control was a result of addressing a doctrinal need rather than reacting to war.

The concepts and how, when, and why nations create a command and control system, have relevance for today's air forces. The history of the UK, US, and Germany in creating their command and control system provides leaders insight into several areas. These include the role of doctrine in shaping an air force; the primacy of centralized control/decentralized execution; the air force role in integrated air and missile defense; and the need to formally cultivate and operationalize technology.

Insight: The Role of Doctrine in Shaping an Air Force

Doctrine played a very important role in the development of each nation's command and control system. Doctrine tells military organizations what to focus on, and what to avoid. Doctrine should serve to guide; it can constrain or help. It is impossible to know if doctrine is correct until it either works or does not work when war arrives. Becoming fixated on a particular doctrine can be disastrous. Having outsiders challenge doctrine is healthy, especially if the doctrine defines the organization. In the case of the UK, it took outside actors, politicians and economic planners, as well as iconoclastic airmen, to de-emphasize the strategic bombardment doctrine in favor of achieving some balance with defense. In the US, it took prohibitive losses for the AAF to acknowledge it had to adjust its strategy, but it continued to believe strategic bombing to be the critical function of an air force even after the failure of the bomber to "get through." As late as June 1944, Arnold stated that "the No1 job of an air force is bombardment" and "the best defense is attack."[1] For both the US and UK, it took political action to settle the doctrinal debates between airmen and soldiers regarding who controls airpower.

The British belief in the effectiveness of offensive operations plus the difficultly of defense led the RAF to focus on offensive operations as the solution to its defensive problems, instead of taking a more balanced approach between offensive and defensive capability. The UK also created a strategic bombardment doctrine after World War I, despite a lack of evidence that it was effective and its inability to bomb deep into enemy territory without fighter escort. An expectation and extrapolation of future bombing accuracy and capability created a belief in the ineffectiveness of direct defense and the contrasting effectiveness of the counteroffensive.

The RAF and Air Corps should have realized that the bomber's technological superiority was probably transitory. Why did they think it would endure when just a few years prior the fighter reigned supreme? The history of warfare is replete with examples of the ascendency of one weapon followed by the ascendency of another that made the older technology less dominant or obsolete. RAF and Air Corps thinking regarding bombers and pursuit aircraft capability was binary. Rather than viewing air power as a system of capabilities, it chose to emphasis a particular weapon. For some reason (probably Douhet's idea of a Battleplane), many airmen believed the bomber had to do it all to prove airpower's capability rather than emphasize a combined arms approach. The bomber could have been the "Queen of Battle" for air operations as the infantry was for ground operations with other weapons supporting. Again, airmen disregarded the historical evidence that a combination of weapons tends to perform better than a single weapon. Finally, the RAF

[1] Arnold, *Report of the Commanding General of the Army Air Forces to the Secretary of War: 4 June 1944*, 2.

and Air Corps did not credit the possibility of defensive pursuit's capability, consistently stating in school texts that the bomber and crews would "just" push through.

In the US, a false appraisal of the strategic environment did not result in a delay in building a command and control system; rather, it was a product of a single minded focus on strategic bombing's efficacy, and an inability or unwillingness to believe otherwise. Strategic bombing was what made air forces different from the other military services.

American airmen focused on bombardment because that distinguished the Air Corps from the other military services. The Air Corps developed its strategic bombing theory under the guise of coastal defense, and justified building bombers to attack enemy naval ships before they came into range of shore. By embracing defense as its *raison d'etre*, it should have also created a command and control system as some in the Air Corps and the Coast Artillery Corps advocated.

Airmen became too invested in their doctrine to see evidence to the contrary. Once Arnold became the Chief of the Air Corps and with war highly probable, he began to focus more on pursuit, yet continued to believe the bomber would get through despite the evidence to the contrary. Cognitive dissonance, the discomfort of holding contradicting ideas, explains why the Air Corps disregarded evidence thorough the 1930s (both from exercises and the Spanish Civil War) that even low performance pursuit with some command and control could make bomber operations prohibitive. Eliminating dissonance requires not rejecting or misinterpreting information to align belief with evidence. An attack on the theory of strategic bombardment was an attack on Air Corps identity. They were too vested in the doctrine to see it was not viable and needed adjustments to maintain an otherwise sound concept.

Spaatz personally witnessed the Battle of Britain and British inability to conduct daylight operations against a rudimentary German air defense system, one that had not fully integrated radar. Yet, the Air

Corps somehow thought the lessons did not apply; that they and their B-17s were different. The AAF continued to steadfastly believe it could operate in daylight without fighter escort. It took massive B-17 losses at Regensburg and Schweinfurt in the summer and fall of 1943 to acknowledge otherwise and shatter the existing paradigm.

German operational doctrine drove the creation of an air-to-ground command and control system. The German concept of warfare influenced the search for a way to improve mobility on the battlefield. The air-to-ground command and control system was a direct outgrowth of the process of integrating a weapon into operations to help create breakthroughs. The wide spread belief that the Luftwaffe was nothing more than an extension of the Army is false. This myth resulted from the Army's growing reliance on airpower as its own resources dwindled. The Luftwaffe developed a bombing capability, but was equipped with smaller bombers due to industrial limitations. German aviators in WWI first began supporting ground troops on their own, and other nations copied the practice.

German doctrine embraced the offensive. Despite having an aircraft reporting service, and a robust AAA system, Germany did not have an integrated and centralized command and control system for homeland defense. It had a warning system well integrated into civil defense. One reason is that fighter pilots viewed their primary function as offensive not defensive. Defensively, they operated under a ground commander. German airmen mirrored the thinking of British and American airmen; they thought their system of offensively attacking the enemy air force would succeed and they did not have a backup. Second, despite a strong tradition of combined arms warfare, Germany inexplicably thought AAA more than sufficient to defend Germany. They attributed more capability to AAA than the available evidence suggested.

As the recent wars in Iraq and Afghanistan end, one of the current "buzz" words is ensuring the ability to operate in "contested environments." The enemy has not challenged the US and its allies in the air or had their command and control systems attacked or degraded. Sometimes it appears as if the concept is new; and it is for this generation. WWI and WWII, however, were "contested environments," both in the air and on the ground, and nations developed command and control systems to operate in those environments. It was a way to orchestrate and provide order for the commander to respond to battlefield events. Belligerents attacked each other's command and control system by intercepting radio transmissions and jamming radio and radar. Each side countered with a myriad of methods in order to continue operating.

Command and control relies on a communications infrastructure. To be effective, air forces require a command and control system that is robust, redundant, and protected. Having a command and control system does not guarantee success, but not having one may mean failure.

As the US Air Force begins to examine the environment in the face of withdrawal from Afghanistan, it must guard against simply adopting a doctrine with which it is comfortable. To best serve the nation, it must unemotionally examine its doctrine and then test it in as unbiased a fashion as possible. It must guard against thinking it is invincible or that something does not apply to it because it has a special weapon or system. Doctrine requires continuous evaluation against new technologies, adjusted as necessary, and attacked to determine its weaknesses. It is the only way to ensure the ability to operate in a "contested environment."

Insight: Centralized Control/Decentralized Execution (CCDE)

Organizationally through 1945, while all three nations' air forces were not independent, air power and its role within the military tended toward a model of centralized control. Airpower was most effective under a centralized controlled and decentralized execution model. By the end of the war, all three nations centralized control of airpower.

During the interwar period, each nation followed slightly different paths before entering WWII. The RAF became an independent service in WWI and Trenchard successfully maintained its status despite Navy and Army efforts and dwindling defense budgets. Once the need for air defense became apparent in light of Germany's military growth, the RAF brilliantly centralized its air defense. Fighter Command demonstrated the importance of CCDE, while a decentralized control model for ground operations proved ineffective in France and initially in North Africa. An effective CCDE model led British politicians to settle the debate. Ironically, for TORCH, even the British did not follow the successful CCDE construct created by Coningham and supported by Churchill.

In the US, the air service continued as a part of the Army through the end of WWII, though the Army Air Forces operated as a de facto independent service. The air service and its airmen argued for centralized control throughout the period, making incremental progress. Finally, politicians (Churchill and Roosevelt) directed the concept after the Casablanca Conference by creating a unified allied air command. The history of American and British airpower during the rest of WWII clearly demonstrate that the CCDE concept is the best construct for the control of airpower and should be the starting point of all planning. Of course, there are exceptions, such as when going after a sensitive target that requires a joint commander or even the national command authority to make the final decision on a particular attack. In general, however, centralized control and centralized execution does not work, especially in a contested environment.

Germany, due to doctrine, had an Army that directly controlled some air power for ground operations. By 1942, limited resources forced the Luftwaffe to centralize all air power in order to meet the needs of the ground commander. In 1944, the Luftwaffe centralized all defensive airpower, but it took until 1945 for the system to be complete. By then, it was too late.

Examples of less than optimal performance or failure in the case of Germany's attack on Britain indicate that some command and control is better than no command and control. No command and control for Germany during the Battle of Britain was disastrous. Despite a less than optimal air-to-air command and control system and limited fighter numbers, the Germans were able to make the cost of Allied daylight attacks prohibitive until 1944 when long-range escort became available. Conversely, an outnumbered UK with a very good command and control system defeated Germany during the Battle of Britain. In both cases, the two air forces contested the airspace over the UK and Germany. The command and control systems of both nations were critical in orchestrating their air forces to parry and counter. Once Germany lost portions of its early warning network after the allied invasion in June 1944, the German command and control system became less effective and so did the ability of the German fighter force to stop both tactical and strategic attacks on Germany and its forces.

CCDE is as critically important today as it was in WWI and WWII because of the scarcity and flexibility of airpower. Limited and dwindling resources will require centralized control and decentralized execution, especially in a contested environment.

Insight: Technology Requires Purposeful Development

The history of command and control provides two major insights regarding technology. First, technology requires purposeful development. Second, airmen must be able to operationalize technology.

The UK established formal organizations to find technological solutions to problems, employed scientists in the Air Ministry, and both the military and political establishment embraced technology. The creation of various committees directed by Tizard to solve a multitude of technological issues is one example. The system however was not perfect.

The UK, as in the US, let doctrinal biases dictate placing very little emphasis on fighter technology to overcome the fighter's inferiority relative to the bomber. By doing so, their doctrine became a self-fulfilling prophecy.

In the US, there was no formal system, and most of the work took place from the bottom up as seen with the Signal Corps development of radar, or funding just enough to keep fighter research and development alive. It was not until the US saw the British model before the US built a full and systematic research and development program between industry and academics, modeling the British.

Germany on the other hand, did not have a systematic approach. As the preeminent historian of the prewar Luftwaffe notes, "The research and development program in aviation lacked intelligent guidance. There was no single body or council to formulate clearly the characteristics of desired research and development and to supervise their execution."[2] Throughout the war the Luftwaffe fielded a multitude of equipment, much of it very good and advanced, yet without guidance there were no priorities and focus to enable it to solve emerging challenges.

Operationalizing technology and purposeful development are intertwined. Operationalizing technology involves taking technology and making it useful. Technological complexity and overload can be hindrances to the application of technology in the field. The US and the UK did a better job of identifying a problem and creating a practical technological solution for application in the field. For example, while the US made only a few MEW radars to provide early warning, the allies quickly modified the MEW to make it relatively mobile, and were able to integrate it into daily offensive tactical operations. The capability the MEW brought to the TACs in Europe could not have been accomplished by any other combination of systems. Conversely, Germany seemed

[2] Homze, *Arming the Luftwaffe,* 215.

unable to operationalize technology to the same degree. Rather than create good, basic, and simple to operate technology, Germany tended to build "gold-plated" systems that required a lot of technical training. They also built too many different systems that strained their production lines and training schools. One such example is the use of both the EGON and Benito control systems, when concentrating on and developing one would have made more sense. Another is the slow development of PPI, which would have decreased the complexity of the Seeburg method of control or the plotting of hundreds of tracks manually on a board/map. With limited resources, German efforts were spread too thin, and the procedures were not well thought out for field use. Finally, it is inexplicable how Germany did not pursue radar when radar would have provided an all-weather "air picture" and tracking capability for its AAA, for which it relied most for defense against air attack. Germany technology itself, however, was very advanced and ahead of its time, such as the use of data links to control aircraft.

Today's command and control systems rely heavily on communications and computers. The fiscal environment and the proliferation of computers and communications technology into every aspect of civilian life means that the private sector can serve as a place to harvest best practices and integrate the latest technologies. Finally, it means that the era of proprietary systems and computer coding must be abandoned. The Air Force must be able to build, repair, and change its command and control infrastructure, leveraging the latest commercial off the shelf products in order to ensure security and the availability of parts. Finally, open architecture systems allow the Air Force to quickly modify its command and control system to adjust to changes in doctrine, the threat, or to simply improve efficiency.

Insight: Integrated Air and Missile Defense is an Air Force mission

The history of these three nations through 1945 indicates that the Air Force should be the lead service for air defense. Too often however, air defense and the command and control required is not well understood because it does not appear to be the primary function of an air force. Simply put, it is not as glamorous as "going downtown and breaking things." Too often, USAF General Officers have made statements indicating the USAF does not provide assets for missile defense, and that it relies on the other services to bring the "toys." Such thinking is dangerous and very narrow. The other services do bring high visibility and very capable air defense equipment such as the Army's Patriot and Terminal High Altitude Area Defense (THAAD) systems, and the Navy's AEGIS. Air defense, however, is not only missile defense; it is also aircraft defense, hence the modern doctrinal term Integrated Air and Missile Defense (IAMD). Successful missile defense at the tactical and operational level requires integrating the systems mentioned above with those of aircraft. Aircraft not only provide defense against other aircraft that can launch cruise missiles, they can also defend against cruise missiles themselves, much as British fighters did against the V-1. Most importantly, the USAF today provides the command and control infrastructure for IAMD. No other service has the ability to integrate, and command and control the various joint capabilities into a comprehensive system for centralized control and decentralized execution. The Area Air Defense Commander, usually the Joint Forces Air Component Commander in US doctrine, centrally integrates the various components of IAMD, and promulgates rules of engagements, and other instructions. The execution, however, is decentralized to the various commanders of the defensive systems due to the time required to make a decision.

As the threat from theater and cross-theater missiles increases, the US Air Force must fully embrace the IAMD mission because it is fundamentally part of what an air force does, and because it is so vitally important to the theater commanders and our partners. To echo what bomber proponent Captain Kenneth Walker stated in 1933 after the Fort

Knox exercises, the air force should take the IAMD mission seriously before another service does.

All nations overestimated the power of the bomber, to an almost religious degree. As Slessor later recalled, "It had always been an article of faith with the Air Staff that the counter-offensive was the most important element in our own defence. I think it must be admitted that we overstressed that doctrine to the extent of seriously underrating the efficacy of fighter defense and providing inadequate numbers of fighters in all but the last of the pre-war expansion schemes."[3]

Airmen must look at history in as unbiased a form as possible, remaining aware of their prejudices and inclinations in order to make valid and relevant decisions regarding doctrine and employment concepts. They must never forget that "those divining lessons from warfare often have preconceived notions of what they seek or are impelled by diverse imperatives—political, military, economic, and cultural—to perceive certain lessons while ignoring others. The lessons of the war [World War I] attributed to strategic bombing a prowess based not on wartime experience but on extrapolations of that experience by airpower theorists that enabled them to claim for airpower decisive significance in future wars."[4] It was this extrapolation that prevented the development of critical command and control procedures until air arms were actually embroiled in war, and led airmen to discount lessons related to having a command and control system. Unfortunately, this directly led to more airmen losing their lives than was perhaps necessary.

The conclusion from the study of these three nations is that command and control is not a panacea, but it enables an air force to manage and conduct its various missions. We would do well to not

[3] Slessor, *The Central Blue*, 166.
[4] Morrow, *The Great War in the Air*, 378.

neglect this oft neglected, little understood, but highly important air force function.

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