The Battle of Britain: The First Integrated Air Defense System

A Monograph

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The Battle for Britain is the only campaign to be fought and won solely by airpower. The research question explored in this monograph was: How did the British integrated air defense system prevent the Luftwaffe from setting the requirements for a German invasion of Great Britain? The British were victorious because their layered defense plan presented multiple simultaneous problems to the unescorted German bombers, preventing them from focusing on their assigned mission. The secret use of radar resulted in the British RAF being capable of predetermining a location of their time and choosing for the British fighter squadrons to engage the bombers. The British ability to understand the changes in the operational environment more swiftly than the Germans resulted in their ability to operate within Germany's decision-making cycle. The design of Col John Boyd's concept of OODA loop is to help better understand the continually changing environment faster than the enemy is to present multiple problems for them to solve, preventing them from achieving their mission. Significant to today's operational environment is how technology can help process the information at the faster speeds and speed up the process to understand the battlefield faster and to operate more quickly than the enemy.

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Abstract

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The Battle for Britain is the only campaign to be fought and won solely by airpower. The research question explored in this monograph was: How did the British integrated air defense system prevent the Luftwaffe from setting the requirements for a German invasion of Great Britain? The British were victorious because their layered defense plan presented multiple simultaneous problems to the unescorted German bombers, preventing them from focusing on their assigned mission. The secret use of radar resulted in the British RAF being capable of predetermining a location of their time and choosing for the British fighter squadrons to engage the bombers. The ability of the British to understand the changes in the operational environment more swiftly than the Germans resulted in their ability to operate within Germany's decision-making cycle. The design of Col John Boyd's concept of OODA loop is to help better understand the continually changing environment faster than the enemy is to present multiple problems for them to solve, preventing them from achieving their mission. Significant to today's operational environment is how technology can help process the information at the faster speeds and speed up the process to understand the battlefield faster and to operate more quickly than the enemy is capable.

Content

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Abbreviations

A2AD	Anti-Access Anti-Denial
AAA	Anti-Aircraft Artillery
ADGB	Air Defense of Great Britain
AOC	Air Officer Commanding
BEF	British Expeditionary Force
Col	Colonel
IADS	Integrated Air Defense System
OODA	Observe, Orientation, Decision, and Action
RAF	Royal Air Force
RDF	Radar Direction Finding
USAF	United States Air Force

Introduction

On June 5, 1940, the German Chancellor, Adolf Hitler, was at a crossroads. The German military had just forced the British Expeditionary Force (BEF) off of the European Continent, and the French national government had surrendered. The result of this meant that Germany had succeeded in taking over or neutralizing the entire European continent with relatively minimum effort. Hitler had grand plans to eliminate Joseph Stalin and his Communist government. Still, he needed to bring Great Britain to a negotiated settlement that would end the fighting in the west so that he could focus all of his efforts against the Soviet Union. Germany didn't have the wartime capacity to conduct a two-front war because it lacked the necessary raw material resources that would fuel the German war industry. If Germany attacked the Soviet Union first, it could gain the required materials to continue a war against either nation. However, if Germany attacked Great Britain first, it would have to husband its resources to preserve combat power to fight the Soviet Union later. Hitler chose to attack Britain first, hoping for a quick victory. When Germany failed to achieve its success over Great Britain, they turned their focus towards the eastern front. They attacked the Soviet Union in what would be the most massive military campaign in humankind. In the short period between July 1 and October 31, 1940, the British Royal Air Force had defied the odds and handed the first decisive defeat to the German war machine.

The British were successful in their efforts against the German military because of their integrated air defense system. This paper explores the network behind the British integrated air system that brought together all of the various pieces and organizations that enabled the air defense system to be successful. The overall success of the integrated air defense system was due to the work of Air Officer Commanding (AOC) Hugh Dowding, the Commanding Officer of the Royal Air Force (RAF) Fighter Command. He understood that the only way to defend the British mainland from an attack was to consolidate the various commands under a single control that could orchestrate their collective efforts. Dowding based his plan on the belief that the British

needed to maximize the German aircraft losses before they could reach their targets as the crucial component to the success of the British throughout the campaign over the skies of Britain. AOC Dowding developed and implemented a defense system against the German bomber formations that reduced their ability to reach their targets. German fighter fuel limitations meant that there would be either limited or no fighter coverage once the bomber formations crossed shortly over the English Channel. Armed with this critical vulnerability, Dowding directed his fighter squadrons to focus their efforts on the unescorted bombers. The German war machine suffered losses that were not sustainable. Ultimately the Germans withdrew the majority of their air forces from the theater to focus on the upcoming Soviet campaign in the east.[1]

The design of the integrated air defense system portion of the Dowding System was the first of its kind, and it enabled the British to centralize their efforts in reducing redundancy in assigning which air squadrons to launch against the incoming German threat. The research question to be explored by this paper is: How did the British integrated air defense system prevent the Luftwaffe from setting the requirements for a German invasion of Great Britain? The evidence supports that much of the success of the campaign belongs to Air Marshall Hugh Dowding's concepts, and thoughts on how he organized the various organizations together were essential for the success of the British. To make his plan feasible, Dowding had to fight for the necessary assets when the British government's focus was creating and equipping new fighter squadrons that could be used on the European continent to aid in the war in France. The overall concept of Dowding's plan for the integrated air defense plan was not limited to the observations of the German formations. He also used the experiences and techniques used during the First

[1] John Turner, "*Analysis of the German Operational Air Failures: The Battle of Britain, 1940*" (master's thesis, Newport, RI: College of Naval Warfare, 1994), 2.

World War that channeled the Zeppelins into the effective ranges of the anti-aircraft artillery (AAA) guns and the flight paths of the British airplanes.[2]

The process used by AOC Dowding to get within the German decision-making cycle was never original or unique. He recognized that the Germans were consistently using the same patterns in all of their formations and did not alter from them. Col John Boyd observed the same observations were being utilized by the Communist forces when his squadron was fighting them during the Korean War. Boyd summarized his comments into a concept known as the OODA (Observe, Orientation, Decision, and Action) loop. This model can be used to dissect the reasons how the British were victorious against the German air force. The existing British air defense doctrine and available equipment positioned around critical locations at the beginning of the air campaign set the basis for the defense plan, and they were expanded upon as the German Luftwaffe showed their doctrine and tactics during the early raids on the island.

This study uses Col Boyd's OODA loop as a comparison template for how the British Air Command made their adaptions to the German tactics to maintain their ability to prevent the German bombing campaign from having their desired effects. With the benefits of hindsight, Boyd's concept shows how an organization can successfully react to an emerging situation to get in front of the German military. First to be examined will be how the British designed their first doctrine and tactics based on their observations of how the Germans fought the air campaign throughout the First World War and how they continued with their refinements based on the observed changes throughout the rest of the war. These observations fed the development of the multi-layered integrated air defense plan. They helped the British position their initially limited assets along the English coastline and around the significant population and war material production centers preventing the Germans from achieving their strategic objectives. How the

[2] Ian Castle, *London 1914-17: The Zeppelin Menace* (Oxford, England: Osprey Publishing, 2008), 16.

British responded to the changing environment defined how they were able to develop and implement updated doctrine and tactics that prevented the German Luftwaffe from obtaining their strategic objectives by setting the conditions for the sea invasion of Britain. Second, during the Interwar Period, the British government subjected the military to several massive budget reductions and disarmament programs. They continued to conduct their refinements to their air defense programs on paper and discussion to further test new ideas without the benefits of large budgets and the ability to field-test multiple new weapons. Lastly, the Battle of Britain serves as the ultimate test of survival for the British people in that they had to fight off a superior air force that had battle-hardened pilots who had largely contributed to the fall of the European continent in the short period of seven months.

To understand how the British were victorious against a superior enemy air force, they will be compared against the concepts of Col Boyd. Boyd based his OODA concept on the idea that individuals are in constant interaction with their environment, and only those who adapt to the changing conditions will survive.[3] Great Britain proved that despite the numerous advantages of the German Luftwaffe in superior equipment and experience, it was not invincible. The Dowding System was the first integrated air defense system in the world. It enabled the Allied war production capabilities to be protected, allowing the focus to increase war material production and not the constant repair of the facilities. Lastly, it added a higher degree of protection to Great Britain, with the fighter squadrons being closer to their targets, which extended their time to fly over the target.

Chapter 1: The Air Defenses of World War I

The basic concepts and foundations for the British integrated air defense system during the Second World War lay with their experiences from the First World War. The new war would

[3] Jeffrey N. Rule, "A Symbiotic Relationship: The OODA Loop, Intuition, and Strategic Thought" (master's thesis, Carlisle Barracks, PA: Army War College, 2013), 6.

introduce many new and deadlier methods for killing that also increased the range of those weapons. These increased capabilities meant that an army could expect attacks deep in its rear areas with as much destruction as a front line weapon. The militarization of the airplane was one example of how new weapon capabilities could threaten the British Isles in a way that they had never seen before. Even before the beginning of the war in 1914, the British had always taken comfort in their beliefs that the British Royal Navy and the English Channel would create the necessary separation from the rest of the European continent to keep the British people safe from an attack or invasion.

Germany's Zeppelin attacks against London were sporadic and limited in its effectiveness as each nation continued to learn how to conduct aerial warfare. During the first two years of the war, the Germans launched only six attacks, usually in small numbers, against the London area.[4] The first tests of the British defense system against the German airships came in the second year of the war on the night of 19/20 January 1915. During that first strike, a single Zeppelin dropped only a couple of bombs over insignificant targets that resulted in little to no damage.[5] Inaccurate bombing sights and almost non-existent night navigation capabilities were the main reasons for their poor performance as opposed to the effectiveness of the British air defenses. The sixth and final Zeppelin attack of the year occurred during the night of 13/14 October 1915, and they would not return over the skies of London until the following September. The overall ineffectiveness of the early Zeppelin attacks lured the British into a false sense of security. Those prolonged periods in between attacks convinced the British military and public to conclude that their initial defense plans were successful enough to deter future German air raids.[6]

In the second half of the war, Great Britain was under more frequent periods of concentrated attacks by the German air force. The attacks resumed on the night of 2/3 September

[4] Castle, *London 1914-17*, 94.

[5] Colin Dobinson, *AA Command* (Suffolk, England: St. Edmundsbury Press Ltd, 2001), 21.

[6] Castle, *London 1914-17*, 91.

1916, with sixteen aircraft launched in a coordinated attack against London with mixed results. During that raid, the Zeppelin airships had upgraded engine systems, capable of increased flight altitudes that kept them were out of range of most of the ground-based guns, increased bomb-carrying capacity and increased flight time. Also introduced were bomber airplanes that could travel at speeds faster than the ground defenses could accurately engage.[7] During the same period of inactivity, the British government had begun a full mobilization of the nation's war effort. Increasing the pilot training program to sufficient levels that enabled some of the newly organized fighter squadrons to remain for the defenses of Great Britain and not hinder the ever-increasing demand for pilots and aircraft in France. Implemented into the integrated defense plan was the addition of searchlight batteries, increased numbers of anti-aircraft batteries, and full-time observation points.[8]

There was a three-month break in attacks between the summer and fall months of 1917. When the Germans returned, they began to rotate from Zeppelins to bomber airplanes as the primary means of delivering the munitions to their targets in London.[9] Updated airplane capabilities brought a change in tactics. The original Zeppelins could linger over their targets for an extended period as they selectively released their munitions.[10] The Zeppelins had previously enabled the British time to bracket their air and ground fires at relatively stationary or slow-moving targets. The advent of aircraft as the delivery means caused the British to alter their defense tactics as the new airplanes moved at a much faster rate of speed, higher altitudes and did not remain over the target for any extended periods.[11]

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[7] Ian Castle, *London 1917-1918: The Bomber Blitz* (Oxford, England: Osprey Publishing, 2010), 13.

[8] John Prior. 2011. "Air Defense- A History of United Kingdom Air Defense in the 20th Century," Air Defense, Accessed 15 July 2019, https://www.airdefence.org/.

[9] Castle, *London 1917-18*, 91.

[10] Castle, *London 1917-18*, 16.

[11] James D. Crabtree, *On Air Defense* (Westport, CT: Praeger Publishing, 1994), 30.

Eleven Zeppelins achieved a decisive victory achieved during the last major raid on London of 1917 on the night of 19/20 October. Despite this victory, the German military leadership saw little benefit in continuing with their current strategy of attacking with large numbers of Zeppelins at one time because their effects were not breaking the will of the British people to discontinue the war. To counter the losses they were sustaining, the Germans continued with their development of more robust airship engines with additional horsepower that would enable the Zeppelins to withstand the wind strengths at higher altitudes. During the winter of 1917, the remaining Zeppelins received a more powerful engine that would allow for them to fly at altitudes more elevated than the British airplanes and anti-aircraft guns. This new capability inspired the German high combat to make one more big push to knock the British out of the war before the full might of the American army entered the war in the spring of 1918. However, disaster struck the Ahlborn Airfield on 5 January 1918 when a fire broke out in the hanger, which housed four of the newly refitted Zeppelins. The fire destroyed the four double sheds in which housed the refitted ships, as well as one additional one awaiting its turn for refitting. This fire effectively removed that airbase from any further service for the rest of the war.[12] Frustrated with these irreplaceable losses, Germany switched to the new bomber aircraft as the primary means of attacking London.[13] Those attacks caused more than 2,000 civilian casualties, but Germany still could not achieve its strategic objective of forcing Britain out of the war.

Between January 1915 and the end of the war in November 1918, the Germans had raided Great Britain in fifty-four separate occasions. They had used a total of 277 sorties in hopes of the destruction, and psychological effects would drive England out of the war.[14] The lack of technology to aid in night bombing and the overall inexperience of the German aircrews resulted

[12] Castle, *London 1914-17*, 90.

[13] Castle, *London 1917-18*, 91.

[14] Dobinson, 22.

in mostly ineffective attacks. The lack of accurate bombsight instruments for the night time operations meant the German crews had to primarily release their munitions based off of the actions of the first element instead of each airship having the ability to determine their targets. At increased altitudes, terrain features were nearly impossible to identify, especially when London imposed nightly blackouts that removed the lights of the surrounding cities as the most accessible landmarks to follow to London.

The British air defense plan did not have the proper coordination measures in place that enabled them to mass effects at a single point in time when the German aircraft were either the most concentrated or at their most vulnerable point. Three significant unsolved dilemmas existed for the British command contributed to their uncoordinated actions during an air raid. First, limited weapon production levels meant that for every anti-aircraft gun assigned to the defenses of London was a weapon that was not being sent to Europe to help with the fighting there. Second, that was the debate of how should the limited number of available air defense guns be positioned. Would the weapons be better in static, fixed positions along the most logistical route for the German aircraft, or should they truck-mounted and conduct a mobile defense because there were not enough AAA guns available? Lastly, should the defenses be in clustered formations that allowed for a concentration of firing, or should they be spread out in a linear structure to cover the most ground and not allow for any unimpeded flight paths for the Germans to exploit?

The first consideration was the need to increase the air defenses and manning for the London defenses would come at the expense of not sending that equipment across the English Channel to France where the war was not going particularly well for the Allies. The nationalized munitions production resulted in a series of various ordnance sizes being available for the London's defenses. The distribution of anti-aircraft guns designated for the protection of London was in small numbers to the areas that required immediate attention. This practice resulted in different calibers assigned to the same area as new weapon systems were made available

throughout the war. Limited personnel and available fire direction equipment meant that the same crew had to calculate the firing data for each weapon and each sub sequential adjustment. The lack of a centralized location that could calculate the firing data for the different types of weapons meant each of the individual firing batteries had to figure their firing data. The time required to calculate two or three different types of firing data for each weapon system significantly slowed down the British gun crew's ability to mass their fires resulting in a peppering effort instead of amassing of their fires.[15]

The second primary consideration for the British was either to emplace the anti-aircraft guns in static, fixed locations or to have a mobile defense based on the direction of the perceived threat.[16] Command and control of the British air defenses would be easier to manage if the air defense guns fought from fixed positions, enabling for better coordination between different elements during an attack.17 The mobile defense option would be able to compensate for the limited number of guns and prevent the Germans from determining any undefended air paths, flying unimpeded towards London. This option meant additional time was required to notify, move, and position the batteries before they could engage the Zeppelins.[18]

The third part of the defense point was whether to establish the defense locations in either a point defense with the guns clustered at critical areas or to position them in a linear barrier concept?[19] The British government decided that the newly organized manpower and material were better utilized for the overall war effort and deployed to the European continent. The air

[15] Crabtree, 23.

[16] Dobinson, 6.

[17] Prior 2011.

[18] Crabtree, 25.

[19] Dobinson, 22.

defense plan was compensated for the reduced air defense capabilities by having the defense forces consisting of mobile gun teams that would operate in designated areas.[20]

After every Zeppelin raid, the British defense forces gained invaluable experiences and a better understanding of the German aircraft capabilities and limitations. Despite an increased number of attacks, the overall effects of the German raids had on the war production, and the civilian population was minimal. The lack of excessive disruption to the country resulted in British society believing that their disjointed defense plan was being highly effective against the Germans.[21] However, the British military command understood that they had to overcome several significant challenges. Towards the end of the war, they attempted to unite all of the separate elements under a single unified command. Communication limitations hampered their effectiveness to mass fires at a single point in time. The British also repositioned the AAA gun batteries in fixed locations in a five and nine-mile radius outside of London instead of in linear patterns.[22] The first observers were initially on-duty police officers stationed sixty miles outside of London. They telephoned in the sightings of the hostile aircraft, to the best of their abilities, the composition, direction, and estimated altitude of the aircraft.[23] Later in the war, the observer duties were transferred to trained military personnel from the Territorial Divisions (the British equivalent to the US National Guard) and positioned in new observation points in thirty and fifty-mile radius circles outside of London.[24] The time difference between first notification and when the aircraft flew over the guns could be a narrow window of time, and often the firing batteries would miss the aircraft.

[20] Crabtree, 25.

[21] Dobinson, 40.

[22] Ibid., 29.

[23] Ibid., 25.

[24] Ibid., 30.

The British Royal Air Force, formally created on April 1, 1918, was credited for heavy losses suffered by the Germans and not the anti-aircraft gun crews.[25] The higher number of confirmed kills from the fighter squadrons and not the gun crews helped to establish the belief in airplane superiority. The advent of German aircraft as the primary means of delivery caused the British to alter their defense tactics as the airplanes moved at a faster rate of speed, higher altitudes and did not remain over the target for any extended periods.[26] This belief led to both sides, believing that the aircraft was superior and would play a dominant role in future wars. The British war effort continued to reflect this belief as they reduced anti-aircraft gun production despite the voices of the few that saw the ground guns as being able to be better based upon their ability to be in a position around the vital population and economic centers. The "fighter first" air defense theory would be echoed throughout the interwar years as bomber and fighter craft development saw increased range, lethality, and the survivability of the aircraft.[27]

This new threat led to the British developing height finding equipment to combat the increased altitudes that the German aircraft were traveling. The British military also experimented with the deployment of barrage balloons that were lashed together with a series of cables preventing German aircraft from flying at lower altitudes, which improved their targeting capabilities.[28] These balloons forced the airplanes to operate at higher altitudes, reducing their bombing accuracy. Concentrating the German aircraft at a minimum elevation assisted the British in determining their cruising altitudes and increased the effectiveness of the anti-craft guns surrounding London. The British fighter squadrons could also location and more readily engage the Germans.

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[25] Donald Nijboer, *Flak in World War II* (Guilford, CT: Stackpole Books, 2018), 11.

[26] Crabtree, 30.

[27] Nijboer, 12.

[28] Thomas E. Griess, *The Second World War: Europe and the Mediterranean* (Wayne, NJ: Avery Publishing Group Inc, 1989), 62.

This belief led to both sides, believing that the aircraft was superior and would play a dominant role in the rest of the war. The British war effort continued to reflect this belief as they reduced anti-aircraft gun production despite the voices of the few that saw the ground guns as being able to be better based upon their ability to be in a position around the vital population and economic centers. The "fighter first" air defense theory would be echoed throughout the interwar years as bomber and fighter craft development saw increased range, lethality, and the survivability of the aircraft.[29]

At the end of the Great War, both Germany and Great Britain believed that the airships posed the potential to be a significant threat to London and the British people. Though London lay exposed to an aerial attack, the BEF fighting in France was the priority of the British war effort, receiving the vast majority of available personnel and equipment. This policy resulted in the air defense plan requirements receiving minimum war resources as thousands of men and equipment were pushed to France as soon as they were ready.[30] It wasn't until the air raids began to have a noticeable effect on the British people was the necessary resources transferred to the defenses of London. Through the German perspective, their intentions for the air raids were an attempt to break the morale of the British people, especially those in London, to help force an end to the war. Despite the exposed defenses of London in the early months of the war, the German airship fleet was never in a real position to threaten the city seriously. Although the German were not victorious in their objective to disrupt the British war efforts, they did succeed in holding back thousands of men and hundreds from being used along the front lines in France and the other theaters of war.[31]

Chapter 2: The Interwar Years

[29] Nijboer, 12.

[30] Graeme C. Wynne, *Stopping Hitler: An Official Account on How Britain Planned to Defend Itself in the Second World War* (Barnsley, England: Frontline Books, 2017), 3.

[31] Castle, *London 1914-17*, 91.

In the years immediately following the end of the Great War, the British government, like most of the other nations involved in the war, started an immediate demobilization of their military forces and made huge slashes in their defense budgets. In the ten years following the war, a period of economic growth enabled most of Europe to return to a level of peace and prosperity. By the late 1920s, several nations began to restart their rearmament programs. Great Britain initially resisted this movement of rearmament. Still, it saw that both France and Germany (Hitler rejected Part V of the Versailles Treaty and established the Luftwaffe in 1934) were developing and producing equipment that was beyond the current capabilities of the British military.[32] Hoping to avoid being dragged into another land conflict, the British began to explore various aerial defense options for the defense of the British Isles that focused on the development of a new generation of fighter/interceptor aircraft. Great Britain's defense efforts were concentrated against the increasing aerial capabilities of France since they considered being the most viable adversary in the next war.[33]

After the war, there was strong advocating by many individuals for the aggressive development of air combat doctrine. Italian theorist Giulio Douhet argued that aircraft was an effective offensive weapon that could rain destruction in economic and population centers as a means to deliver an early end to the war. The bombers would be capable of retaining their combat formations and effectiveness after getting through the air defenses and reach their targets. If those theories were proven to be accurate, then the British military knew it was no longer immune from a direct attack from an opposing nation.[34] Despite the new arguments, the intense brief remained

[32] John LaSaine, *Air Officer Commanding Hugh Dowding: Architect of the Battle of Britain* (Lebanon, NH: University Press of New England, 2018), 52.

[33] Austin M. Duncan, "Innovation Determinants of the World's First Integrated Air Defense System," *The Strategy Bridge*, accessed 15 July 2019, https://thestrategybridge.org/the-bridge/2018/5/3/innovation-determinants-of-the-worlds-first-integrated-air-defense-system.

[34] Griess, 55.

that the British Royal Navy and the English Channel would be able to protect them from any attack led to inadequate preparations with the air defense plan.

In December 1929, the Air Defense of Great Britain (ADBG) was the first large committee that Great Britain formed to study their defense options as a whole.[35] Heavily influencing their final report was the writings of several early aerial theorists, such as the Italian Giulio Douhet. Douhet's 1921 essays reasoned that airpower was inherently an offensive weapon because of the speed and flexibility that it offered when compared to the limitations that the ground and naval forces. The second theory of Douhet was the impossibility of intercepting aircraft and thus reasoned that the bombers could not be stopped and would always get through.[36] These conclusions influenced the ADGB committee to believe that the British government's efforts would be more efficient, focusing on airplane development instead of on ground-to-air defense capabilities. After Germany began its rearmament program in 1934, Great Britain saw the growing threat war was becoming severe and accelerated its air force development program.[37] The danger that the British were most concerned with was the possibility of Germany would strike at their commercial and industrial centers, as well as London, with the development of the long-range bomber capabilities.[38]

In July 1936, Air Marshall Hugh Dowding was appointed Air Officer Commanding of RAF Fighter Command. Dowding challenged the lessons learned from the previous war and believed that a unified air defense system could prevent the bombers from getting through the air defenses and dictating the movements of the ground defenses. If the collective defense systems were brought together under a single chain of command that could direct their actions, then the

[35] John Ferris, "The Theory of a 'French Air Menace,' Anglo-French Relations and the British Home Defense Air Force Programmes of 1921-25," *Journal of Strategic Studies* 10, no. 1 (1987): 65.

[36] Griess, 56.

[37] LaSaine, 57.

[38] J.R.M. Butler, *Grand Strategy, Volume II* (London: Butler & Tanner Ltd, 1957), 17.

attacking aircraft could be forced to react to them. His concept for the air defense of Great Britain challenged the widely popular brief within the British government in Douhet's theory that "the bombers would always get through." His air defense concepts would need a significant catalyst to cause the paradigm shift in British thinking on how to defend their island.

Dowding was one of the few people in the British Government who did not agree with the British Prime Minister Stanley Baldwin's 1932 declaration. Dowding's stance helped push the discussion for a land-based defense system.[39] As the AOC of Fighter Command, Dowding consolidated all of the individual pieces for his air defense plan under a single system where with the proper coordination; all of their effects could be massed together against their targets. Dowding's pleas for increased air defense spending fell on deaf ears by the British government because of the impact airpower was having during the Spanish Civil War of 1936-38. Adolf Hitler sent the German Condor Legion to fight under Francisco Franco, not only to support another fascist government but to test the capabilities and weaknesses of the infant German Luftwaffe. The improved skills and ranges of the bombers and fighters demonstrated that significant advances in aviation doctrine and tactics had developed since the conclusion of the First World War.[40]

In November 1938, the ADGB was slow to react to the changes in Spain with increased aircraft range and payloads. The committee only partially approved a revised aerial defense plan for Great Britain with the agreement that the RAF's Fighter Command would control all of the fighter aircraft, anti-aircraft artillery, and the searchlight and balloon companies in a collective effort.[41] It would be the 1939 invasion of Poland that the threat of an aerial attack would be only a matter of time for Britain's homelands.

[39] Turner, 17.

[40] Nijboer, 18.

[41] Butler, 18.

Before the end of the year, the ADGB committee again amended their report based on new casualty estimates that they believed the German military had the potential of inflicting upon the London civilian population. The updated numbers now included estimates of upwards of 200,000 civilian casualties per week, with 66,000 people killed during the air raids.[42] Those casualty estimates concluded Britain needed to prevent an aerial knockout blow from occurring. The basis for the updated reports partially reflected the destruction that had happened in the Spanish Civil War and the Blitzkrieg Campaign in Poland. The senior leadership of the national government and the military believed the fortifications in Belgium and France were strong enough to repel a ground invasion by the German Wehrmacht, which would prevent the Luftwaffe from being able to stage in bases that would be close enough to range Britain. If Great Britain's RAF could augment France and her allies in holding back the German military in Europe, then would be little need to have a robust air defense system in Great Britain. This decision resulted in the majority of the British defense efforts going to fighter development instead of ground defenses. That fatal conclusion started the moment that the British ground forces needed to be strong enough and ready to deploy to the continent in the event of war to prevent an aerial attack from occurring.[43]

Chapter 3: The Battle of Britain and the Dowding System

The origins of the British integrated air defense system could be found in the years immediately following the conclusion of the First World War. Great Britain’s defense plan struggled throughout the First World War because all of the instruments of defense operated under different chains of command. The additional coordination between the separate commands slowed down the reaction time of the air defenses to focus their efforts against the Zeppelins and later, the bombers that were attacking London and the surrounding areas. Despite the overall

[42] Wynne, 8.

[43] Wynne, 12.

success against the German Air Force, the British saw the benefits of consolidating all of their defense assets under a single command were essential for the next war. This consolidation concept was one of the first items addressed during the interwar period when the British began focusing their defense efforts against an air attack.

When the German government decided to focus its' attention on Great Britain, the lone remaining obstacle to complete their domination of Europe, the next few months would unknowingly be critical in the determination of the outcome of the war. Within six weeks, the German ground forces had pushed their way through France and had pushed the BEF off of the continent. Throughout Operation Dynamo, at a high cost, the British RAF was able to provide the necessary protection for the Royal Navy to evacuate the majority of the British and French ground forces from the port of Dunkirk. Although the British RAF provided sufficient air cover for the ships as they pulled away from France, they sustained heavy losses in both aircraft and pilots, which was initially irreplaceable against superior German aircraft numbers and skills. During the Battle for France, the French Air Force had lost almost 500 of their 650 fighter aircraft, and the BEF had lost all but sixty-six of the 260 Hurricanes.[44] Those losses to the British RAF represented twenty-five percent of their entire air fleet. After the loss of those irreplaceable experienced pilots, AOC Dowding urged that no additional fighter squadrons be sent to France to provide air cover to the BEF.[45]

The quick defeat of the British Army caught the entire air defense plan unprepared in the event the Luftwaffe launched an immediate attack on the British island. But before Adolf Hitler could launch a seaborne invasion of the island, Germany would first have to establish complete air superiority over the skies of Great Britain. Beginning on July 10, 1940, and for the next three and a half months, the Luftwaffe launched a massive air campaign to establish air dominance

[44] Loren M. Olsen, "The Battle of Britain, A Study in Command and Control" (master's thesis, Carlisle Barracks, PA: US Army War College, 1991), 5.

[45] Griess, 73.

over the skies of Great Britain with the concept of crippling Great Britain's desire to continue the war and capability to conduct air operations.[46] Once the Germans established dominance in the air, they planned to execute a seaborne invasion. During those three months, the British integrated air defense system proved capable of what was considered an impossible task: to hold the German military back while the nation mobilized for war. The air campaign for the battle of Britain is one of the only examples in modern history where an entire campaign was decided by air power and not by sea or land. The British integrated air defense system was the first of its kind, and it proved to be highly successful in preventing the German military from establishing the conditions to enable a sea-borne invasion form occurring.

Attributing to the success of the Dowding System was its' four major components; the Channel Home radar system, the human observers of the Royal Observer Corps, the predicted plotting system in the Filter Room, and the placement of radios in the Hurricane and Spitfire airplanes.[47] The concept of placing them under a single command stemmed from the successes and failures from the First World War when Germany launched their Zeppelins against the civilian population. During that conflict, the individual sections of the air defense plan were not always able to act together in a unified effort against the Zeppelin threat. The shortage of available equipment and personnel, as well as the general inability to timely and accurately locate the Zeppelins, often resulted in a piecemeal effort engaging the German aircraft.

The real power behind the Dowding System was that it had a clearly defined chain of command, and all of its authority began in one room, aptly named the Filter Room.[48] The Filter Room collected all radar and visual observer reports. Based upon the initial radar detection point and the estimated direction and speed of the aircraft, operators in the Filter Room would calculate the interception coordinates for the British RAF Fighter Group headquarters that would launch

[46] Turner, 6.

[47] LaSaine, 105.

[48] Ibid., 69.

the appropriate number of aircraft.[49] The interception points were the most suitable location to engage. The design of the four RAF Fighter Groups Headquarters control rooms mirrored the layouts of the main Filter Room, and they had command authority of all of the air defense units operating within their boundaries.[50]

The British military's use of a layered defense as part of their integrated air defense plan prevented the German Luftwaffe from being able to obtain air superiority, thus avoiding the setting of the conditions for a German seaborne invasion of the islands. The British added to their existing doctrine from the First World War and expanded on it with the introduction of new technology, specifically radar.[51] The RAF Fighter Command also positioned their initially few assets in critical locations throughout southern England that prevented the Luftwaffe from achieving their objective: the destruction of the British RAF.[52] Defeating the German Air Force through innovative technology and tactics, ever-adapting to the changing situation, the British prevented the German military invasion of Great Britain.

The results from the air campaign during the First World War had lasting effects on the key individuals who were now responsible for the defense of Great British under a single organization, the RAF Fighter Command. AOC Hugh Dowding served as the commander of the RAF Fighter Command and was the champion for the air defense program. Dowding established an unprecedented network of control rooms and landline communication networks that developed a highly centralized and organized command and control center that was capable of filtering out unnecessary data. This organization enabled the Filter Room team to focus on the single task of

[49] Ibid., 126.

[50] Ibid., 127.

[51] Oliver Lorenz, "The Battle of Britain: An Analysis in Terms of Center of Gravity, Culminating Point, FOG, Friction, and the Stronger Form of War" (master's thesis, Fort Leavenworth, KS, US Army Command and General Staff College), 1989, 9.

[52] Patrick O'Maura, "History's Role in Operational Design and Planning: How Germany's Failed Invasion Provides Insight in the US and Chinese Perspectives on A2AD" (master's thesis, Quantico, VA: USMC Command and Staff College, 2013), 7.

tracking the German aircraft and calculating the predicted locations where the British fighter squadrons could engage them before reaching their targets.[53] The ability to bring all of these nodes together and get the various organizations to work together as a united front brought together Dowding's theory of an integrated air defense plan. This unprecedented cooperation between the fighter aircraft command, the anti-aircraft artillery, and the searchlight and the balloon companies enabled Dowding's theory of integrated air defense to be successful.

Air Marshall Dowding understood that to have a successful air defense plan against a highly trained and battle-hardened German Luftwaffe, all aspects of the island's defenses had to be answerable to him under a single chain of command. The air defense system consisted of five separate elements that, when layered together, concentrated the German aircraft at a predicted location where they engaged by the waiting British fighter squadrons. This unity of authority became the key to success for the Dowding System because it controlled all aspects of the air defense system for the entire British mainland.

The Home Channel radar system made the initial contact with the German Luftwaffe as they were flying over the English Channel. The Royal Observer Corps established visualization of the aircraft as they passed over the shores. They maintained contact with them by tracking and reporting their movements as the Germans neared the population and industrial centers. Located several miles away from London and other key locations, the barrage balloons formed walls connected by cable netting would force the Luftwaffe to fly at a known minimum elevation. Co-locating the searchlight batteries with the anti-aircraft guns helped in aiding them engage the aircraft as they passed over the balloons. The higher altitudes forced the Luftwaffe to concentrate their formations and, like during the First World War, reduced their bombing effectiveness. The RAF fighters would engage the Luftwaffe at a predetermined location based on the calculations that the personnel in the Filter Room based on the flight direction, speed, and altitude that the

[53] LaSaine, 70.

Royal Observers had provided. That location could also be in conjunction with the barrage balloon positions as the searchlights, and anti-aircraft batteries were already tracking the enemy.[54] Every part of the Dowding System was geared towards the concentration of the German bombers when they were unescorted by their fighters and were at their most vulnerable position before the RAF could engage them.

The Filter Room

The main Filter Room was located outside of London in an underground bunker at RAF Bentley Priory, a converted country house.[55] Dowding had divided the island into four regions of responsibility with a clearly defined chain of command that reported directly to Bentley Priory. The purpose of the main Filter Room at Bentley Priory was to receive the initial reports of an impending attack and determine which region was to receive the responsibility for engaging the threat. After passing the details of the enemy formation and the tactical command to handle the situation as the Section Commander saw fit, Bentley Priory monitored the events until the German aircraft had turned back towards the European continent. Each of the region and sub-sector headquarters Filter Rooms was designed and laid out in the same manner, having the same setup and equipment as Bentley Priory to maintain the same standard operating picture. After the Channel Home radars confirmed that the aircraft had begun to pass back over to the English Channel, the Filter Room would regain command of the situation.

Each of the four regional headquarters had direct command of all of the air defense assets within their area of responsibility. The regional headquarters would have between one to three fighter wings assigned to them, and each fighter wing had three fighter squadrons of fourteen fighters assigned. The sector stations would rotate the fighter squadrons for intercept duty to

[54] Butler, 18.

[55] Prior 2011.

conserve both pilot strength and the aircraft readiness until the Luftwaffe crossed into their area.[56] This technological advantage enabled the British air command to save their few aircraft resources and kept their aircrews rested on the ground until the radar system had detected German aircraft flying overhead. The alternative was to have the small group of fighters scattered across the skies' patrolling until one of them had a visual sighting of the Luftwaffe bombers. After an aircraft sighting occurred, it could take a considerable amount of time to notify the other patrols to consolidate together before attacking. By then, the British might have missed the opportunity to mass their forces against the Germans and would have to rely on smaller numbers of aircraft to engage. The fighters could arrive low on fuel, which would reduce their engagement time against the bombers. The radar system solved this issue by enabling the British pilots to remain resting on the ground, before launching to engage the Germans with the maximum amount of fuel available to them when the engagements began.

The Radar System (Range and Direction Finding: R.D.F.)

First tested in May 1936, the front line of defense for the island of Great Britain was an experimental radar system by a team led by Henry Tizard, and the system was capable of detecting incoming aircraft at a range of up to 100 miles away.[57] Through the use of multiple towers, Tizard proposed that his team could determine the necessary mathematical calculations that would enable British fighter aircraft to intercept the enemy aircraft at a predetermined time and location based on what he referred to as the “Principle of Equal Angles.” The first line that was determined would be the baseline that connected the point where the radar first detected the enemy aircraft and the direction from the airfield where the on-call RAF fighter squadron was to respond. The second line calculated what would be the estimated flight path to the predicted

[56] Griess, 62.

[57] Randall Degering, *“Radar Contact!” The Beginning of the Army Air Forces, Radar and Fighter Control* (Maxwell AFB, AL: Air University Press, 2018), 1.

target based on the current direction of the aircraft. The final track determined the predicted intercept point where the RAF fighters would meet the inbound German bombers. The plotted map locations used the estimated speed and altitudes of the Germans that had been provided by the Royal Observers. They factored in the time necessary for the British pilots to reach that point once they were airborne and en route. This last line would become known as the "Tizzy angle" and be the course vector for the British pilots when they took off from their airfields.[58]

Tizard's team was able to produce the manual rulers and other necessary calculations over four months. The small four-person team proved capable of quickly and accurately determining the flight paths; the British military began to order the practice targets to start making course changes, forcing the team to work faster to make the intercept point corrections.[59] Determining the grid of the approaching aircraft was completed with greater confidence when multiple radars reported a signal and provided multiple signals that would triangulate to the estimated enemy location. Slow construction of the required Channel Home Station radar towers along the English coastline meant a minimum number of triangulation lines were available to teams that had to determine the Tizzy Angle. The reduced number of provided information placed extra pressure on them to work faster and maintain their accuracy until enough radars stations were operational.

The radar capabilities of the British military was just one part of their over success against the German aerial invasion. At the beginning of the war, eighteen of the twenty-four intended Channel Home Station Radars were in position and operational. Positioned inland of the coast, the radar towers faced outwards towards the European continent. Earlier versions of the towers had proven unable to calculate inbound aircraft data accurately when they were positioned too far inland and away from the coast because of the terrain. The only successful method to

[58] Duncan, 2018.

[59] Degering, 2.

receive a return pulse was to transmit over flat terrain. The concept of the system was sending out a series of pulses from three, 240-foot tall towers and received back on an adjacent set of four towers.[60] The time required for the first set of towers to send out a pulse signal and received back on the second set after bouncing off an object was used to calculate the estimated direction and distance the aircraft was away from the first set of towers.

This secret capability of the British military enabled the fighter squadrons to remain on the ground for extended periods, allowing for maximum crew rest and aircraft maintenance instead of patrolling the skies of Britain in search of the Luftwaffe. The British fighter squadrons could then be alerted and launched at the pre-calculated time that enabled them to arrive at the intercept point with the maximum amount of flight time remaining to engage the Germans. The system was capable of detecting aircraft taking off of airfields located in France and tracks them as they flew over mainland Europe and the English Channel. Without having to worry about conserving enough fuel to return to their home station, the RAF pilots would be sent to the nearest airfield for refueling operations after each engagement.

The Air Defense Research Committee accidentally discovered the principles of R.D.F. while they were researching ways to track weather storms. The early versions of the system used reflected electrical echoes were able to determine the direction of inbound aircraft up to ranges between 80 to 200 miles. They received their most accurate data when the aircraft was at a range of around 100 miles away.[61] The system was capable of sending out pulse signals in one hundred degrees angle for every tower, ensuring an overlap with multiple towers.

One of the main shortcomings of the Channel Home Stations was that they could not determine friend from foe, type of aircraft, or their cruising altitude. If the radar picked up an unknown aircraft or any friendly aircraft that the Filter Room was not tracking as flying that day,

[60] Crabtree, 54.

[61] Griess, 60.

valuable time was lost determining coordinates and sending aircraft towards an inexistent threat. The risk was if a real danger emerged at the same time that British fighters could not adequately respond. For unknown reasons at the time, the radar towers were not able to track aircraft when located inland. Interference from the rolling terrain forced the British to position all of the towers in a single row along the coastline, removing any capability to create a layered capacity.

Despite these intelligence gaps, the British military was the only organization at the start of the war to have such a system. With the sudden start of the war, only eighteen of the twenty-four stations were operational along the eastern and southern coastlines of the island. To help disguise the real intention of the radar systems, they resembled commercial radio antennas to the German pilots that flew over them over periods of daylight.[62] The success of the radar system was in the redundant confirmation systems that were in place that ensured that the radar signal received was not an anomaly. Stationed behind the radar towers were the human observers from the Royal Observation Corps that would confirm the aircraft direction detected by the R.D.F. reports.

Additionally, the observers were positioned at regular intervals to confirm and expand on the radar reports by providing the size and composition of the aircraft, as well as their estimated flying altitude, something that the radar systems were not capable of determining. Connected via dedicated, underground phone lines, the observers had direct access to the Filter Room. The Observer Corps' reports reduced the shortcomings of the infant radar system with the additional information that they provided in their sighting reports. The two portions of the observation system that provided the initial intelligence picture in the Filter Room were known as Ground-controlled interception.

The Royal Observer Corps

[62] Gregory C. Clark, "Deflating British Radar Myths of World War II" (master's thesis, Maxwell AFB, AL, Air Command and Staff College), 1997, 36.

One of the most significant shortfalls of the British radar system was that it was only one layer deep. Any of the towers were inoperable due to mechanical issues or from gunfire from the Luftwaffe that meant the possibility of German airplanes being able to enter British territory undetected. To prevent such an event from occurring, positioned behind the towers were twenty-eight, and later on, thirty-two, Royal Observer Corps districts in overlapping positions leading towards the economic centers of Great Britain. These human observer positions had an established communications network that had direct access to RAF Fighter Command at Bentley Priory and the local military authorities.[63]

The original members of the Royal Observation Corps were persons who had been deemed unfit for active military service. These observers played a vital role in the Battle of Britain because they confirmed or denied the presence of German aircraft, as well as expand on the initial reports with additional information about the formations. Their reports enabled the Fighter Squadrons not to have to conduct as many roving patrols patrolling for enemy aircraft as they would have if the radar system were not in existence. This organization enabled the pilots' critical additional rest time in between missions, and the maintenance crews' time to repair and maintain the battered aircraft, as well as the conservation of precious fuel.

Assigned in regularly spaced intervals behind the Channel Home radar stations, the observers provided the Filter Room with updated reports of the German aircraft as they passed over their positions. Along the approaches defending the Greater London area, observers were positioned in concentric circles thirty and fifty miles away. This spacing allowed for enough time to get their reports through to the fighter squadrons and give them enough time to position themselves between the Germans and their intended target. The observer teams stayed connected with their respective Group Headquarters initially through the telephone system and later via radio; they were the first ones to report speed, size, composition, estimated flying altitudes, and

[63] Wynne, 17.

direction of travel. At the Filter Room, the Mechanical Director (formerly the small four-person teams who worked on the Tizzy Angle) took the data and calculated the present course, future position, and azimuth, evaluation to target interception, and estimated time to target. After the target location was determined, the Filter Room watch officer notified the appropriate Air Group Headquarters to launch their fighter squadrons for the interception of the German bombers. The azimuth and elevation of the German bombers, as well as the estimated time for them to reach their target, was concurrently forwarded to the anti-aircraft gun crews stationed around the expected target. This information enabled the gunners to set the time fuses for their ammunition.[64] Each eight gun battery had a similar machine, the British Stroud No. 1 Mark IV Height-Finder that was in the Filter Room for calculating any altitude corrections.[65]

The Barrage Balloons

The final attempt to concentrate the German bombers before the British fighter squadrons attacked was with the barrage balloons that surrounded the significant economic and population centers. The last three portions of the integrated air defense system of the Dowding System consisted of the barrage balloons, the searchlight crews, and the anti-aircraft batteries. They worked together to disrupt the cohesion and effectiveness of the German bomber formations by forcing the aircraft to climb to altitudes, hindering their bombing accuracy, as well as, made them more vulnerable to the anti-aircraft weapons. Though the barrage balloons never had enough cable or wire nettings to damage many aircraft, they still performed an invaluable service of clustering the German aircraft together to avoid any potential entanglements. The British positioned the barrage balloons outside of London and the economic centers as semi-fixed obstacles in front of the searchlight and anti-aircraft batteries.

[64] Crabtree, 45.

[65] Nijboer, 20.

The Balloon Command had the responsibility of protecting key cities and infrastructure sites, ports, and harbors. When cabled together, the barrage balloons forced the German bombers to climb to altitudes around eleven thousand feet, which allowed the anti-aircraft guns to engage them more effectively.[66] Linking the barrage balloons together helped to keep them clustered together, as well as to prevent the Luftwaffe dive bombers from flying through the ground cables. Forcing the Germans to operate at higher elevations caused them to concentrate together and release their bombs based on the lead bomber to maintain target accurately and overall bombing effectiveness.

The Searchlight Companies

The Luftwaffe leadership decided that bombing under cover of darkness was the best way to reduce the devastating effects of the British aircraft and anti-aircraft guns. They used the cover of darkness to conceal the cruising altitudes that negated the British fighters and anti-aircraft guns' ability to find and target them accurately. The protection of darkness enabled the Germans to bomb at lower elevations, which improved their accuracy until the British ordered and enforced blackout conditions during the night. Countering the German advantages of night bombing, the British added searchlight batteries to the war effort, a weapon that first saw used during the siege of Paris during the Franco-Prussian War.

The British had successfully integrated searchlights into their defenses from the First World War with the barrage balloons. AOC Dowding ensured that the maintaining of the sixty-inch wide searchlights was part of the limited British inventory during the Inter-War Years. He understood the value of the searchlights in the verification process in conjunction with the radar system and the human observers. Once the German aircraft were flying overhead, the

[66] Dobinson, 46.

searchlights became one of the only means of identifying the aircraft. The Dowding Plan incorporated the searchlights by employing groups of three searchlights, often one 150cm type light and two 120cm type lights, emplaced in a triangular formation, with fifty meters spaced between them.[67] Each of the searchlight clusters was spaced in regular intervals every 6,000-yards that stretched from the Solent and east of London to the Humber-Tyne-Tees district, a distance of 90 miles.[68]

The lights were positioned behind the barrage balloons to help identify the German bombers' altitude before the anti-aircraft guns could go into action against the aircraft. With a known elevation of the barrage balloons, estimating the difference between the balloons and the bombers was simplified. Combined with the early models of elevation estimation equipment, the searchlights helped confirm what the machine was computing for the fire direction crews. The searchlight batteries maintained visual contact with the bombers until the fighter squadrons arrived on the scene.

The Anti-Aircraft Artillery Batteries

So severe and quickly done was the dismantlement of the British military in the years immediately following the end of the First World War that only one brigade of AAA guns and one battalion of searchlights remained.[69] Despite all of the indicators pointing to a greater need for anti-aircraft gun batteries, the ground forces responsible for the air defense suffered from the "fighter first" defense. Before the Battle of Britain began, they lacked more than half of the number of AAA guns that were required to emplace adequate protection of the island against an air attack.[70] The air defense plan called for AAA guns positioned in the clusters of four, and there

[67] Dobinson, 280.

[68] Ibid., 285.

[69] Crabtree, 37.

[70] Nijboer, 12.

were to be nine station clusters two miles forward of the expected targets along the estimated travel path of the aircraft. The most significant difference between the current emplacement plan for the guns and that from the First World War was the positioning of the same caliber weapons at a location. This decision often meant that a firing point would be short of its allotted number of weapons to streamline the firing data computations. When Poland fell in September 1939, only 695 of the 1,296 guns called for in the 1939 Air Defense plan were in position and crewed. At Scapa Flow, where the British Northern Fleet laid in port, only eight of the twenty-four guns were in place.[71]

The advent of the radar system and increased accuracy of the Royal Observation Corps' reports enabled the coastal gun and the anti-aircraft batteries to more effectively target enemy aircraft flying over them. There was a disproportionate kill ratio between the anti-aircraft gun crews and the RAF Fighter Squadrons. The debate discussed among the senior military leadership was too much effort and resources put into the anti-aircraft guns that could have been better used elsewhere in the ear effort? Except for the Quick Firing 3-inch (QF 3 in.), which was a holdover from the First World War, the majority of the air defense weapons could easily reach the maximum cruising altitude of the German Air Force. The Junker JU 88 had a cruising altitude at 17,000 feet, while the Vickers 3.7 inch and the Vickers 4.5 inch cannons could respectively range up to 25,000 and 26,000 feet above sea level.[72] Despite being capable of reaching beyond the maximum cruising altitude of the Luftwaffe, the British air defenses scored a minimum number of confirmed kills, as opposed to the RAF fighters. On August 16, 1940, the Germans launched nearly 1700 sorties against multiple targets. The air defense guns scored a total of nine confirmed kills, while the RAF achieved a confirmed kill count of thirty-six.[73] In March 1941, after the Battle of Britain had concluded, but continued to receive sporadic air raids, the air defense guns

[71] Wynne, 16.

[72] Nijboer, 48.

[73] Dobinson, 223.

scored seventeen confirmed kills, and in April achieved thirty-nine and a half confirmed kills with an average round expenditure of an average 3,195 rounds for each confirmed kill.[74] During the last major Blitz attack against London, on the night of 10/11 May 1941, 541 sorties were flown. At the expense of 4,150 rounds fired from all calibers, the gun crews received credit for only shooting down two bombers, and ten others damaged.[75]

Despite the limited number of confirmed kills from the air defense gun crews, their intent was not to achieve a high number of enemy kills. The fighter squadrons and the air defense guns needed each other to accomplish the mission of protecting Great Britain from invasion. Prime Minister Winston Churchill believed that the air defense guns served the symbolic purpose of providing morale to the people of Great Britain, regardless of their success. He ordered batteries to be stationed in Hyde Park so that the people could hear the firing.[76] The air defense guns had two main jobs given to them throughout the Battle of Britain. Their first job was deterrence. Their gunfire helped deter the German Luftwaffe from attempting to engage targets at lower cruising altitudes in tight formations and forced them to fly above the firing where the British fighter squadrons could more readily engage them. Damaged German bombers were easier targets for the British Hurricanes and Spitfires, who held the advantages of speed and altitude against the bombers who were without a fighter escort of their own. The flak fire not only damaged the aircraft, which had to be repaired, reducing the number of available aircraft for the next mission, but they also killed and wounded crew members. The second job the gun crews held was the destruction of the bomber aircraft.

The Fighter Squadrons

[74] Ibid., 296.

[75] Nijboer, 60.

[76] Crabtree, 58.

AOC Dowding saw elements of his 1936 ADBG plan for incorporating the fighter squadrons evolve as the original method concerned German aircraft launching from Germany instead of from France.[77] Another change to that plan had strategic long term benefits were to concentrate his limited aircraft against where he considered the main effort of the expected German attack. Number 11 Group received the bulk of the air squadrons as their area of responsibility London and the counties in southwestern England. Number 12 Group covered central England and received the next largest contingent of aircraft. Numbers 10 and 13 Groups were the far northern and southern tips of the island and initially received a minimum number of squadrons until the capacity existed to build up their strength.[78] Despite pressure from the national government, Dowding resisted sending individual replacement pilots to depleted squadrons and instead rotated entire squadrons from the more active sectors to the less active ones to reorganize and rebuild the tired ones.[79] Dowding also empowered his Group Commander with authority to call the adjacent commander for reinforcements directly in the event additional fighters were required.[80]

Dowding's based his plan on how to execute the fighter squadron portion of the integrated air defense plan on one of two possible assumptions of the German Luftwaffe. The German military could concentrate all of their forces in a pointed attack to attempt a decisive victory over the British Air Force in a single blow, or they could wage a war of attrition and wear down the British defenses. The quick, decisive victory over the French and British air forces over the skies of France reinforced the German belief in the superiority of their aircraft and pilots. When the Filter Room had sent the launch orders and flight information to a particular Group, they were responsible for launching the appropriate number of response aircraft. The Groups

[77] LaSaine, 69.

[78] Ibid., 79.

[79] LaSaine, 124.

[80] Griess, 62.

were also responsible for coordinating the ground defenses that surrounded the critical population and infrastructure centers throughout the countryside. Around each of the population or infrastructure centers would be a local commander who had tactical control of all of the air defense elements present. The flow of the centrally controlled British chain of command meant that all of the pieces of the defense system were under the local RAF leadership, ensuring that the nervous ground defenders knew when friendly aircraft would be operating overhead to prevent fratricide incidents. This coordination meant that the German aircraft could be under constant threat of attack throughout the entire time they were over British territory.

Based on the limitations of the German fighter aircraft, few of them could provide escort duties to the bombers after they have reached the British Isles due to their fuel carrying capacities. The bombers would travel over Great Britain unprotected from the British Hurricanes and Spitfires. Even if fighter escorts were available, Dowding forbade his fighter squadrons from attacking the German fighters, and to focus their attention and efforts against unescorted bombers. The primary target was always the bombers. AOC Dowding saw the German bomber as the center of gravity for the German aerial campaign over Great Britain, and to remove it from the board would end Germany's aspirations for British conquest. Each part of his defense plan was focused on the identification of the bomber formations before they passed over the English Channel; wait for them to be unescorted by their fighters before forcing them into the waiting British fighter squadrons.

From the British military perspective, the requirement to defeat the Germans was to cluster as many of their bombers together near their maximum cruising altitudes where they would tighten their formations at slower traveling speeds. This action made it easier for air defense guns to engage and damage as many of the aircraft as possible. Damaged aircraft were taken out of the rotations to be repaired, reducing the number of bombers available for the next attack. Killed and wounded bomber crewmen, reduced morale, and placed additional stress on

the crews within the formations. Damaged aircraft would break from the flight formations and becomes easy prey for the fighters to engage and destroy them.

Chapter 4: Colonel John Boyd's OODA Loop

It is challenging to take a concept and successfully apply its principles to a previous conflict to demonstrate the effectiveness of the theory. Col John Boyd's OODA (Observe, Orient, Decide, and Action) loop is such a concept that can be applied to an earlier conflict to be analyzed. Boyd based his theories from his own combat experiences during the Korean War against the Chinese and North Korean Air Forces. Boyd recognized that the enemy repeatedly employed a series of consistent patterns in their aerial maneuvers. Until the American pilots began to understand the patterns, they were not able to operate inside the Chinese and North Korean Air Force's decision-making cycle. When they were able to exploit the Chinese and North Korean pilot's patterns, control of the skies tipped back over to the US forces. The aerial mismatch during the early portion of the war led to many costly US Air Force (USAF) defeats. This mismatch only changed when the pilots learned to recognize the repeated patterns, causing the Kuhnian paradigm shift in how the pilots conducted aerial combat.[81]

Upon the conclusion of the Korean War, Boyd's next assignment was Maxwell Air Force Base, Alabama. Boyd began a period of reflection because he wanted to understand how the USAF had gone from the Communist forces controlling the skies over Korea until the tide turned in favor of the US forces. He tried to understand how the American pilots were able to maintain a 10:1 kill ratio throughout the second half of the war.[82] He developed mental patterns of the Communist pilots during his aerial engagements with them and began formulating the initial observations on their tactics and procedures. Those observed patterns helped Boyd to sketch out

[81] Frans Osinga, *Science, Strategy, and War: The Strategic Theory of John Boyd* (The Netherlands: Eburon Academic Publishers, 2005), 91.

[82] Ibid., 41.

in his mind on how a person could manipulate his environment and prevent it from being shaped by his enemy. Most of his observations were born out of man's natural human behavior to survive on our terms.[83] His observations of the Communist pilots showed that while their aircraft were superior to the Americans, the American pilots were better trained. Recognizing that the Communist forces had superior advantages with their aircraft in both quantity and quality, he saw their weakness was in the pilots' abilities to maximize the full potential of the aircraft.
Boyd developed a conceptual thought process of determining the decision cycle of your enemy and gets him to react to multiple moves at a time.[84] Boyd sought to create concepts that exploited operations and weapons capabilities that inhibited the enemy's ability to respond to his actions and adapt to the ever-developing situation.[85] Boyd saw that once you created enough confusion and disorder to the enemy's thought process, he lost the ability to react to multiple conditions at a given time. OODA loops help us gain a sense of our environment and begin to understand the challenge before us. When a conscious person becomes aware of the evolving changes to their environment, they seek different ways to understand why the changes are occurring.[86] The OODA loop is not just a single loop, or problem set, but rather a series of interrelated events that are happening simultaneously.

The foundational concepts behind the OODA loop help explain how each of the four parts contributes to the overall understanding of a complex problem(s). The OODA loop describes the human interaction among the individuals that are trying to gain an advantage over one another in a competitive environment. Having an understanding of what the variables are how they are affecting you and your mission helps you understand the decision-making cycle that

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[83] John Boyd, *A Discourse on Winning and Losing* (Maxwell AFB, AL: Air University, 2017), 316.

[84] Grant Hammond, *The Mind of War: John Boyd and American Security* (Washington DC: Smithsonian Institution Press, 2001), 7.

[85] Ibid., 123.

[86] Osinga, 269.

you need to be operating. Those same variables have the same effect on you as they do on your opponent. Whoever can understand how to manipulate those variables fastest best and most effectively, can gain the initiative and operate within their opponent's decision-making cycle, creating dilemmas for them to solve instead of focusing on their mission. The key is to process your OODA loop as fast as possible and continuously reassess the situation for feedback faster than your opponent can. The first two parts of OODA, Observe, and Orient, are where the individual internally processes the events that are occurring. The third and fourth parts, Decide and Act, are associated with the externally related parts feeding into the problem set.

When we compare how AOC Dowding applied Boyd's concepts to his integrated defense plan, we saw that Dowding used the first two parts of ODAA, Orient and Decided, to attack which the patterns that the Germans operated on. The pattern exploited by the British was the German Luftwaffe lacked long-range fighters that could serve as escorts to the bombers. When left unescorted, the German JU87 Stuka dive bombers and Junker JU 88 conventional bombers could not maneuver around the smaller and faster British Hurricanes and Spitfires. Their inability to outrun or outgun the British resulted in losses that weren't as easy to be replaced as British losses.

An additional observation that Dowding exploited was that the Luftwaffe leadership was unable to see past their biases that the British couldn't withstand the might of the German military after their successful conquest of Europe. The Germans failed to see the multiple defense layers of the British plan designed to reduce their ability to locate and engage their intended targets effectively. The aerial campaigns in both Spain and Poland proved that the German air force was comfortable with their tactics and was not attempting to evolve as aircraft technology improved. They failed to adapt an aircraft that had long-range flight capabilities and preferred to expand on where they were already successful: close air support aircraft. Without proper, consistent fighter escort, the German bombers were no long term match for the British fighter squadrons who were fighting on their homelands.

The British executed the third and fourth parts of the OODA, Direct and Action; they used the integrated air defense system to work to isolate the bombers from one another by forcing them to fly above the barrage balloons. This movement assisted the British in increasing the accuracy of their anti-aircraft guns, causing damage to the bombers that made it easier for the fighter squadrons to complete their destruction. The Action portion of OODA was the implementation of the entire Dowding System beginning with the use of radar to track and determine the direction of travel of the German bombers. The observers expanded on the radar reports by providing estimated altitudes, and the size and composition of the formations. The barrage balloons, searchlights, and the anti-craft guns all forced the bombers to climb to heights that reduced their bombing effectiveness and reduced their speeds to where the British fighters held the advantage.

Chapter 5: Significance for Today's Environment

In today's complex operating environment, the United States and her allies around the world have the increasingly difficult task of using the available technology to our advantage instead of it acting as a hindrance. The increased availability of technology enables different ways and means to gain a competitive edge over your opponent. With most of the current technology being available on the open market, the possibility exists to neutralize all advantages before the fighting begins. In light of the potential reduction in technological capabilities in a future conflict, all participants must look to options that are not able to be compromised, such as organization for combat and the methods in which they conduct their operations. The ability to remain adaptive and having continuous learning and reevaluation of the environment could be one of the few ways to maintain any advantage.

The technology of today is advancing at such a rate that the ability to accurately and timely process the information can become a hindrance to operate just as easily to enable it. Technology can process information faster by helping you understand the operational patterns of maneuver of your enemy. Understanding the environment can produce opportunities to be able to control the tempo of the conflict by using the tools at your disposal, which enhances your understanding of how the environment causes you and the enemy to operate. The use of technology can present multiple dilemmas or problem sets for the enemy to deal with simultaneously, slowing down their decision-making cycle to react to what you have introduced into the environment.

An example of neutralizing advantages by means other than technology is through the use of the local geography. The geographic terrain can allow for nearly endless position opportunities that can deny the air or ground as an avenue of approach to an attacking force. One of the challenges associated with penetrating an enemy's integrated air defense system (IADS) circle in a land conflict includes a thorough understanding of how positioning guidance for the air defense assets can create or take away opportunities for both sides. The rolling terrain can quickly go from wide-open areas to narrow, restricting ground. This type of terrain is supportive of a multi-layered defense structure where the enemy can position assets of all kinds in an overlaying manner, preventing a smooth penetration. The opposite occurs when the battlefield is over the open oceans. Layering your defenses is not possible with the various island chains that dot throughout the vast ocean. The seas enable an approaching force to move closer to the enemy without being seriously challenged. The distances between those island chains can limit the attacking force's ability to resupply it, which in itself is a restriction to the oceans that permit open access. Lack of control of sea paths can force the attacking force to add hundreds of miles and several weeks of travel.

Proper organization of the sensors helps each side understand the situation of the operational environment and what factors can be changed. The number of available sensor and

weapon systems on the battlefield means that you cannot destroy everything but need to be selective in your targeting that maximizes the desired effects. The integrated air defense system employed throughout the Battle of Britain has several lessons learned and tactics that are significant to the reactions in today's changing environment. One of the essential concepts drawn from the British is how to emplace limited assets that maximize coverage over a broad front. Maintaining the flexibility to shift forces around the battlefield enables the movement of assets to critical points during the fighting. It prevents the enemy from gaining any advantage after removing one of your systems from the field. The attacker needs to be able to see which assets, once removed from the battlefield, create a zone of separation from the others and allow the attacking force to advance to create a successful penetration of the enemy's IADs.

Continuous learning has two main parts: consistently reevaluating the environment and being able to restructure your force as the situation changes. Maintaining the capability to always being able to reevaluate your environment that helps you understand what is occurring and how often it changes. The second half of continuous learning can readapt or restructure your organization to the constant motion of the situation. Remaining adaptive means, you consistently are looking at what is changing in the operational environment and what you need to do to influence these changes. Boyd demonstrated different techniques that help you gain an understanding of the internal and external environmental factors surrounding you and continually reassessing the situation. The military force that can execute this task faster and more efficiently can gain the advantage over their enemy because they are thinking and moving more quickly, causing additional dilemmas to be solved.

Adaption includes understanding how your opponent is operating in the environment. The second part of adaption is an understanding of how you can alter or manipulate the situation in a manner that your enemy doesn't understand that changes are occurring until it is too late. Observing the actions and patterns of your enemy helps you to identify where you can make changes in the environment. After applying a change, you wait to see if the enemy remains the

same or if they are adapting to the adjustments used to allow for you to begin operating within their decision-making cycle. Adapting means to have the ability to change as the situation consistently evolves. Having the ability to overlap your assets helps prevent exploitation from occurring. AOC Dowding's employment of both human and mechanical means of identifying and maintaining contact from the time the aircraft took off from their bases in Europe until they began their return flights were critical to the overall success for the British. If the German military was able to remove one portion of the Dowding Plan, there was another layer of observation or active defenses to cover that gap.

The competition for not having enough men and resources will remain to be a factor on today's battlefield. Military budgets will never reach the levels where all of the desires are fore filled, and nations will be required to do more with less. There will never be enough equipment and personnel to satisfy all of the demands of the theater commanders. The employment of the British integrated air defense system throughout the Battle of Britain offers lessons learned in either an offensive or defensive campaign. If you can create a zone of separation around your forces, it can remove several of the advantages that the opposing force had at their disposal to prevent you from maintaining the initiative. Boyd's thoughts on observation help the attacking force maintain the initiative or the defending military forces the ability to withstand the advances of their opponent. The application of the lessons learned from the employment of the British integrated air defense system throughout the Battle of Britain is still applicable to today's offensive or defensive campaign.

Chapter 6: Conclusion

Today's operational environment continues to grow more complex every day with the advent of new technology that increases the range and lethality of weapons. That technology can provide a distinct advantage to whoever holds it; however, there can always be ways to exploit a gap in the system. The ability to think faster than our adversary by creating multiple dilemmas for

them to deal with at a single time is the one way to retain the initiative. Technology can help with creating those dilemmas, but they could just as quickly become the obstacle that prevents us from victory. No one solution can solve the Anti-Access Aerial Denial (A2AD) problem set in today's complex environment. The United States needs to maximize the advantages that the difficulties present so that we can gain the benefit of operating within the decision-making cycle of our opponent.

Boyd's concept for the OODA loop is an example of how to gain an advantage over the enemy by presenting multiple problems to consider at one time that prevents understanding of what will happen next. Operating within the enemy's decision-making cycle is one example of how to take away the initiative from your opponent. Boyd based his approach for his observations that a better-trained pilot flying an inferior aircraft could outmaneuver inferior-trained pilots in superior aircraft. The OODA loop concept shows us that having several technological advantages doesn't guarantee you success if you are not able to maximize the full capability of the technology that is available.

AOC Hugh Dowding's multi-layered, integrated air defense plan offered several simultaneous dilemmas for the Luftwaffe at one time. They were unable to continue operating in their operational environment without suffering unsustainable losses to personnel and aircraft. The concepts that Dowding employed were a mixture of new and old technology, sophisticated computers (for the time) to a human being out in the open field observing the formations flying overhead. The multiple layers of the integrated air defense system prevented the German Luftwaffe's highly trained and technology superior air force from setting the conditions for the German military's seaborne invasion of the island.

The concepts that were exercised by both Dowding and Boyd demonstrated the ability to penetrate the enemy's decision making cycle and being able to operate inside of it without the enemy being made aware. At the beginning of this paper, the research question to be explored was: How did the British integrated air defense system prevent the Luftwaffe from setting the

requirements for a German invasion of Great Britain? Dowding brought together multiple defense elements under a single organization that was more potent together than if they were employed individually. Though both individuals applied the OODA loop concepts differently, they both created multiple dilemmas for their enemy, who was superior in many aspects but did not understand how to maintain the advantages that they had. Being able to see, think, and maneuver faster than your opponent was how Dowding and Boyd were able to work inside their respective enemy's decision-making process. The dilemmas they presented to the enemy were not always highly sophisticated, but they gained the initiative by offering multiple problem sets that aren't able to be answered simultaneously.

Dowding's concept of a multi-layered air defense system that operated together was the real power behind the overall success of the British. Boyd saw the limited skill levels of the communist pilots as a weakness that was exploited by the superior training of the American pilots. The air defense concepts that were emplaced by Dowding before and throughout the Battle of Britain serves as one of the few large scale examples of a successfully integrated air defense plan can serve as a baseline for future conflicts.

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