Women's Auxiliary Air Force radar operator Denise Miley plotting aircraft on cathode ray tube of RF7 receiver in Receiver Room at Bawdsey Chain Home radar station (Courtesy Royal Air Force, Imperial War Museum, Goodchild)

The Chain Home Early Warning Radar System
A Case Study in Defense Innovation

By Justin Roger Lynch

The Germans were aimed to facilitate an amphibious landing across the Channel, to invade this country, and so to finish the war. . . . Mine was the purely defensive role of trying to stop the possibility of an invasion, and thus give this country a breathing spell. . . . I had to do that by denying them control of the air.

—Air Chief Marshal Hugh Dowding

The United Kingdom began the Battle of Britain in an unenviable position. After the fall of France and evacuation of Dunkirk, Britons were justifiably concerned about Germany's next move and the potential for an attack on England. Fortunately, when the Luftwaffe attack came, the British government had already created the world's first integrated air defense system.

The Chain Home early warning radar system played an important role in Great Britain's defense during the Battle of Britain. The system's ability to warn the Royal Air Force (RAF) about incoming Luftwaffe attacks helped restore a measure of Britain's isolation from continental states, contributing to the resistance to and eventual defeat of Nazi Germany. Much of the story of the Chain Home system is already known. Today, however, its creation serves as a case study in military innovation; it shows the importance of allowing strategy to inform the acquisition process, adapting rapidly during war, and having the right team to manage development and implementation.

Context

British scientists created the Chain Home system during a time when the relative strength of the offense and defense was shifting. During World War I, trench warfare challenged the logistics of the day, hindering the exploitation of tactical victories and therefore preventing armies from achieving decisive results for the majority of the war.[1] During the interwar period, some theorists believed the creation of powerful bomber aircraft would allow air forces to bypass enemy armies and geographical boundaries, shifting the balance back toward the offense.[2]

Airpower's growing offensive capabilities changed Britain's strategic outlook. During previous conflicts, the British relied on the English Channel and the Royal Navy to prevent powerful continental armies from invading. The combination of the two formed a barrier that had remained intact for centuries.[3] British fleets protected England from attack by the Spanish Armada in 1588, by Napoleon at Trafalgar in 1805, and by German land forces during World War I. Airpower threatened to allow rivals to bypass the Channel and the fleet, negating Britain's traditional defense. Adversaries possessing powerful air forces would be able to directly target the British population, industry, and infrastructure. In some ways, this returned the British to a vulnerability they had not experienced since medieval times.

At the same time, Nazi Germany's increasingly aggressive rhetoric and powerful air force convinced Britons they needed to develop a defense against their most likely threat.[4] The Luftwaffe had demonstrated its potential during the Spanish Civil War by bombing Guernica.[5] A war between Germany and Britain promised to see similar actions. By the late 1930s, the Germans planned an invasion of England that relied heavily on using the Luftwaffe to strip British defenses and to destroy the population's morale via terror bombing.[6] As a result, the British began to develop a system to defend themselves against aircraft in the same manner the Channel and Royal Navy had defended against ground and naval forces.[7]

The Creation of Chain Home

The British government began to dedicate significant resources to the development of radar in January 1935. The government asked Robert Watson-Watt, a scientist at the National Physical Laboratory, about the feasibility of creating a radio death ray. In February, his team conducted the Daventry experiment. They mounted a short-wave British Broadcasting Company transmitter and a receiver onto commercial vans, then transmitted radio waves along the flight path of a bomber to see if aircraft would deflect radio waves.[8] He reported that while death rays were unlikely to succeed, radio waves could detect aircraft.[9] By June, he demonstrated bistatic continuous wave (CW) radar, which separates transmitters and receivers in order to generate interference when an object flies between the two. While an advance, bistatic CW radar was too limited for practical use. In September, Watson-Watt's team demonstrated the pulse radar detection the Chain Home system would eventually use.[10] One of the government officials who received Watson-Watt's report reacted by proclaiming, "Once again Britain is an island."[11]

The government approved construction of a coastal radar system while research was still ongoing. It authorized the system in September 1935, the same month Watson-Watt tested pulse radar detection. In December, it approved the expenditure of £60,000 to build 5 stations.[12] Each transmitting station consisted of a pair of 100-meter-tall steel towers with 2 dipole arrays hanging on wires between them. The receiving stations were east-west and north-south running dipole antennas mounted on approximately 245-foot-tall wooden towers.[13]

After proving the concept, the British government began construction of a complete system. Coastal radar systems went into continuous service in the spring of 1938. By September 1939, the government had installed 20 stations along the majority of Britain's east coast, establishing the Chain Home system.[14] For approximately £10 million, Britain created a system that detected aircraft out to 120 miles, providing roughly 20 minutes warning, from technology that did not exist at the beginning of the acquisition process.[15]

Early versions of the Chain Home system had two major problems. The first was its inability to detect low-flying aircraft. The original system detected aircraft between 25,000 and 1,000 feet above ground level, creating the potential for German aircraft to evade detection. To resolve this issue, the RAF added Chain

Justin Roger Lynch served as an Active-duty Army officer before transferring to the Army National Guard. As a civilian, he has served in multiple roles in the national security enterprise, including roles focused on emerging technology.

Home Low, a series of shorter portable towers that could detect aircraft flying at 500 feet.[16] The second problem was the skill needed to interpret radar signals. Early displays used oscilloscopes that required complex calculations to determine target locations.[17] The creation of the Plan Position Indicator, which showed the target's position on a map displayed on a cathode ray tube, resolved the issue by reducing the number of calculations needed and making the display more instinctive.[18]

The Chain Home system quickly became an important part of Great Britain's defense. With the system in place, the British received a warning. German aircraft staged for their attacks by gathering in France in full view of the Chain Home system.[19] Combined with information from Ultra and the Observer Corps, Chain Home gave the RAF time to intercept the Luftwaffe before it could bomb RAF bases or civilian populations, allowing the British to save their resources for an eventual counterattack.[20] While they were far from completely safe, they could use their isolation to protect their strategic base from the German army and, as necessary, use their island as a staging area for forces to fight on the continent, as they had in World War I and the Napoleonic Wars.

Lessons for Military Innovation

One of the most important lessons from the development of Chain Home is the need for strategy to inform operational needs and therefore the acquisition process. The interwar period was a time both of dramatically changing military technology and miniscule defense budgets. The RAF was primarily focused on creating a strategic bomber force. Many of its leaders were convinced that bombers would always be able to make it through air defense systems and that strategic bombing could independently win wars. As a result, other parts of the air force, such as Fighter Command, were usually neglected during budgetary decisions.[21]

Rather than dedicating their limited resources toward the latest new technology or trying to match their potential adversaries, the RAF and British political leaders decided they needed to defend the Home Islands from the type of air attacks they experienced in 1917 and 1918.[22] Their determination led to an investment in Fighter Command, which, with support from its political allies, decided that it needed advance notice of air forces coming from the continent to prevent adversaries from gaining control of the air—thus the need for Chain Home.[23]

Chain Home's development also testifies to the importance of rapid innovation in war. The system was a direct response to the advent of effective bomber aircraft, strategic bombing concepts, and Adolf Hitler's aggressive rhetoric. The system subsequently transitioned from a theoretical concept in January 1935 to an operational coastal defense system in September 1939.[24] Walter Kaiser claims, "It is probable that never before or since has such a major technical advance been so widely and successfully deployed in such a short time."[25] If the British government had been slower to act in recognizing its problem set, initiating research, or implementing construction, the system might not have been ready before the Battle of Britain. Even if Chain Home had not existed, the Luftwaffe might not have been able to destroy either Britain's will or capacity to fight. It is likely, however, that without a warning of incoming German aircraft, more RAF fighters would have been destroyed on their runways, and the Luftwaffe would have dropped more bombs on British cities.

It is also unlikely that Chain Home would have been ready if the RAF had not used an iterative development process. Developers using iterative processes make incremental changes to their product rather than try to create a perfect solution from the start. Each iteration is an opportunity to learn rather than a verdict on the system's potential. This allows for less-than-perfect advancements that are still improvements and for regular real-world tests throughout the development process rather than waiting until the end to test the whole system.

An iterative development process can create useful systems more quickly than one that seeks perfection from the start. The Chain Home team developed the program incrementally, developing and implementing flawed systems as long as they were an improvement to the current system and there was a reasonable probability the flaws could be fixed. Watson-Watt tested his theory using existing technology designed for different purposes.[26] Six months later, he had developed a prototype and received the funding needed to create a working system.[27] The first system's inability to detect low-flying aircraft or function without significant mathematical expertise by the user also did not halt its production. Instead, the government accepted that it would need to continue iterating the system's design. The willingness to accept an imperfect design in order to generate progress allowed the government to continue advancing the project and create the Chain Home system before the Battle of Britain.

A third lesson from the development of Chain Home and its integration with Fighter Command is the importance of having the right team in place to foster the growth of specific innovations. It can be tempting for innovative thinkers to believe their idea's or program's merits should stand on their own. This is, somewhat unfortunately, not true. Great ideas and programs rarely survive the uphill climb against bureaucratic inertia based solely on their merits. Programs also need leaders that can shepherd them through the existing system. The expertise to do so, and the bureaucratic, diplomatic, and emotional intelligence it requires, is just as important to program implementation as tactical and technical expertise. In this case, Chain Home had a military champion, entrepreneur, and technical expert.[28]

Hugh Dowding served as the military champion. He advocated for radar within the military bureaucracy, ensured that military personnel partnered with engineers to make sure they both understood operational needs and how the system could perform, and helped develop the tactics the RAF could use to capitalize on Chain Home's capabilities, particularly for night airborne interceptions.

Watson-Watt was the group's entrepreneur. He negotiated with government organizations and industry groups, suggested the line of stations that eventually became Chain Home, and helped acquire the funding streams to turn the group's ideas into reality. Sir Henry Tizard was the technical expert. His committee helped anticipate the system's potential capabilities and issues, including the limitations of air interception, how to communicate air warnings, information quality control, and how to guide aircraft to their targets. Without all three performing their roles, it would have been far more difficult to identify radar's potential, acquire the funding needed to develop it, and integrate it into Fighter Command.

Team composition may differ based on the technology being developed and the system being worked through, but every team needs technical, military, and bureaucratic expertise. Without a technical expert, teams struggle to understand the nuances of development, purchasing, creating requirements, and maintaining new capabilities. This can result in unrealistic expectations, new technology that does not actually perform the task it was designed for, and long-term maintenance problems.

Military experts serve several roles. They help ensure technology will be effective by identifying operational needs, potential friction points during real-world use, and how a particular capability will fit in with the rest of the military. Military experts connect their team to the operational force, easing implementation. They also help add legitimacy so that the acquisition system will take the program seriously.

Bureaucratic experts are necessary because development and acquisition take place in a vast, confusing space filled with red tape. However, they are also filled with opportunities for those who understand the system to make a meaningful difference. A team member who understands the Federal Acquisition Regulation, Other Transaction Authorities, and a host of other regulations, processes, and personalities allows a team to move through the acquisition process and focus on shipping the product instead of fighting a bureaucracy.

Lessons about effective development and acquisition are incredibly relevant for the joint force. The 2018 National Defense Strategy notes that "our competitive military advantage has been eroding" in an environment defined by rapid technological changes and other factors.[29] The ability to identify actual and potential strategic threats, define capability deficits, and create solutions will be an important part of retaining an advantage.

Today's defense development and acquisition systems can learn from the history of the development of the Chain Home early warning radar system. While the above lessons are helpful, perhaps the most important lesson is the focus and willingness to take risks shown by Dowding, Watson-Watt, Tizard, and their teams. Radar systems did not exist in 1935 when the government agreed to fund one. They based their path ahead on the sense of urgency created by their strategic environment, a prototype, and the belief they could iterate their way to a successful system. Without a similar attitude, any group of innovators is less likely to succeed. **JFQ**

Notes

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[6] William L. Shirer, *The Rise and Fall of the Third Reich: A History of Nazi Germany* (New York: Simon & Schuster, 1960), 760.

[7] Walter Kaiser, "A Case Study in the Relationship of History of Technology and of General History: British Radar Technology and Neville Chamberlain's Appeasement Policy," *Icon* 2 (1996), 32.

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[10] Merrill I. Skolnik, "Fifty Years of Radar," *Proceedings of the IEEE* 73, no. 2 (1985), 182.

[11] James, "A History of Radar," 344.

[12] Otto Kreisher, "Radar from World War II Until Today," *Naval Forces* 3 (2007), 71–72.

[13] Ibid.

[14] Skolnik, "Fifty Years of Radar," 38.

[15] Kaiser, "A Case Study in the Relationship of History of Technology and of General History," 37.

[16] Ibid., 38.

[17] Kreisher, "Radar from World War II Until Today," 70–71.

[18] Kaiser, "A Case Study in the Relationship of History of Technology and of General History," 39.

[19] Kreisher, "Radar from World War II Until Today," 71.

[20] Joseph F. McCloskey, "British Operational Research in World War II," *Operations Research* 35, no. 3 (1987), 454.

[21] Hart, *Clash of Arms*, 37–38.

[22] Williamson Murray, *Military Adaptation in War: With Fear of Change* (Cambridge: Cambridge University Press, 2011), 156–158.

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[24] Skolnik, "Fifty Years of Radar," 38.

[25] Kaiser, "A Case Study in the Relationship of History of Technology and of General History," 41.

[26] James, "A History of Radar," 344.

[27] Skolnik, "Fifty Years of Radar," 182.

[28] Alan Beyerchen, "From Radio to Radar: Interwar Military Adaptation to Technological Change in Germany, the United Kingdom, and the United States," in *Military Innovation in the Interwar Period*, ed. Williamson Murray and Allan R. Millett (Cambridge: Cambridge University Press, 1998), 282–283.

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