Article

The RAF and its Approach to Science in The Interwar Period

By Mark Russell

Biography: Mark Russell graduated with a 2:1 in History in 1985 and has worked in professional services ever since. He returned to academia in 2015 and graduated with an MA in Air Power: History, Theory and Evolution from the University of Birmingham in December 2017. His dissertation looked at whether the RAF was a learning organisation in the period 1925 – 1935, with special reference to how the Air Exercises helped the RAF develop and test tactics and technology. His current research interest is the RAF in the interwar years and how the organisation managed technological change.

Abstract: This article considers the scientific resources available to the RAF in the interwar period, and how it used those resources to address one of its most pressing problems, namely the need to improve early warning of attacks against the UK. Ways of addressing the problem of early warning and its ultimate solution through the development of radar are used as a case study to look at whether this technology could have been developed earlier by the RAF.

Introduction

Early warning was not a new concern; during World War One the Chief of the Imperial General Staff (CIGS), General Sir William Robertson, noted 'the distance in time from the coast to important places like London is less than the time required by most of the machines we have got to ascend to the necessary height.'[1] The technology the RAF relied on before radar was sound mirrors (or acoustical mirrors as they were often referred to). The development of these was begun by the War Office during World War One, and their development continued throughout the 1920s and into the 1930s. The sound mirrors detection ranges never exceeded 25 miles, yet despite this, the RAF did not appear to have commissioned studies to actively look for technologies that could detect incoming aircraft at extended ranges. The development of radar to resolve this problem was not the result of a long-term approach by the Air Ministry to use science to solve operational issues; indeed, in 1948 Air Chief Marshal Dowding described the 'romantic discovery and development of Radio Location'.[2]

Before looking at how the RAF tried to address the early warning problem, it is useful to understand radar's history. In the mid-1930s, radar was not a new concept, either in terms of the scientific thinking behind it, or its practical demonstration; in 1904 a German engineer, Christian Hülsmeyer, demonstrated a technology that can be recognised as radar.[3] Hülsmeyer patented his 'Telemobiloscope' in Germany on 30th April 1904, with UK patents following in June and November 1904. His demonstrations to shipping lines were reported globally, including on 19th May 1904 by the New York Times; as a result, the concept was in the public domain. In 1922, Guglielmo Marconi, an Italian engineer and long-distance radio transmission specialist, had proposed a similar system to Hülsmeyer's but this again did not spur practical development.[4] Various papers published in the interwar period also suggested aircraft could be detected by radio waves.[5, 6] There is no evidence however that the Air Ministry or any of the committees that advised it on scientific or technological matters knew of these developments, or considered them to be useful.

Technologies that can be recognised as radar were also developed elsewhere in the British military establishment. In 1928, LS Alder of the Royal Navy's HM Signals School 'had proposed to Admiralty [sic] a scheme for the detection and location of objects by radio.'[7] The entry in the Royal Engineers' Invention Book by Butement and Pollard on 26th January 1931 for a Coastal Defence Apparatus' can also be seen as proposing a form of radar.[8] The RAF appeared unaware of these developments, likely due to the lack of an inter-service scientific forum at this time.

This failure to recognise the potential of inventions was not restricted to radar; for example, Guy Hartcup, a military historian, notes that the proposal of gear synchronisation in order to allow a machine gun to fire through a propellor arc, had been made in both Britain and Germany before 1914, predating Anthony Fokker's invention and implementation of this.[9] The question then is what organisational structures and approaches the RAF had in place

during this period, and hence whether these might have proposed a radio-based solution to early warning earlier.

The first British body aimed at bringing science to bear on aeronautical problems, set up in 1909 under the auspices of the War Office, was the Advisory Committee on Aeronautics. Its role was to look at 'problems arising in connection with … aerial construction and navigation.'[10] It thus had a very practical focus, rather than the broader scope to consider what science could offer to solve wider problems. The Secretary of State for War, John Haldane, did see a role for theoretical science, saying it should seek solutions 'by the application of both theoretical and experimental methods of research.'[11] However, the committee was reactive, responding to requests from the Services, rather than being proactive and volunteering ideas of how science could help solve problems facing them. Its effectiveness thus depended on the questions it was asked, and whether these were the key ones. This practical, reactive approach was to be the hallmark of most Governmental scientific bodies that followed it until the mid-1930s.

In 1920 the Advisory Committee on Aeronautics evolved to become the Aeronautical Research Committee (ARC), which, instead of reporting to the Prime Minister as Chairman of the Committee of Imperial Defence, reported to the Secretary of State for Air and the newly created RAF. It advised the Secretary of State for Air on 'higher matters of research', but it was focused on aeronautical matters, and so again did not consider wider air defence issues.[12] The committee continued to be reactive, and until 1935, was made up largely of members of the aircraft industry, therefore it could, perhaps, only have been expected to focus on research that would improve the aircraft which industry sought to build and sell. This was an essentially practical organisation, not one that was looking at basic science for the next generation of technology; the focus was more on the incremental improvement of existing technologies. So, while the ARC was a body created to bring science to bear on answering questions that the RAF might ask it to look at, it had no broader remit.

The RAF could call on other bodies for scientific support. These included the Aerodynamics Department of the National Physical Laboratory (NPL), which built its first wind tunnel in 1902, and its first supersonic wind tunnel in 1922.[13] The Royal Aircraft Establishment (RAE) at Farnborough also carried out aviation research across a range of areas associated specifically with the problems of flight and aircraft. Both bodies, especially RAE, were focused on research into the specific problems of flight. The Department for Scientific and Industrial Research (DSIR), established in 1916 as an independent ministry, became the responsible body to 'organize all the scientific work which is of common interest to the fighting services.'[14] This would seem to have made it an ideal body to have organised more wide-ranging research such as early warning, because clearly all the Services needed to be able to locate enemy aircraft. However, DSIR did not request or drive research in this area, perhaps because the Services had different needs around early warning; the RAF needed long range early warning, in contrast to the point defence of the Royal Navy and Army. The DSIR executed work in the

early 1920s to debunk stories from Germany about 'death rays' that could detonate explosives, but this did not lead to the further consideration and investigation of whether radio waves could detect aircraft.[15]

These were all external bodies that the RAF could call on, but in 1924 it also appointed a Director of Scientific Research (DSR) to be responsible for scientific research. This is the point at which the RAF might have been expected to begin to seek scientific advice to find solutions to the early warning problem. In 1940, Charles Grey reported 'the Research Department hunted for things, and the Department of Technical Development developed them into a state of being technically useful.'[16]

The first Director of Scientific Research, Harry Wemperis, was described by war correspondent, Ronald Clark, as 'an able engineer.'[17] Many years later Sir Henry Tizard was sceptical of the value of the post of DSR (which he had declined), saying 'He [DSR] had no responsibility, for instance, for radio research.'[18] Physicist and radar pioneer, Albert Rowe also comments on this, saying It is odd that … armament, airships and radio were not his [DSR's] concern.'[19] This may explain why Wimperis as DSR was not looking at radio-based ways to address the early warning problem – it was not his area of responsibility, or area of technical expertise, hence turning to physicist Robert Watson-Watt in early 1935 for the definitive answer on whether a 'death ray', rumoured to be under development in Germany, was possible.

A key part of DSR's role was coordinating the various bodies that were undertaking research for the RAF, and providing 'the necessary liaison between those who carried out fundamental research on the problems of flight, those whose task it was translate theoretical results into planes that flew, and those who physically piloted the planes.'[20] As this description shows, the role was firmly rooted in the challenges of flight; there was no idea that the role would look more widely at the world of science to see what it could provide as possible solutions to broader problems, such as early warning. So, neither DSR nor the ARC were expected to engage in basic research that had no clearly defined purpose, hence they would be unlikely to think broadly about how wider scientific developments might be of use.

This is not to suggest that the RAF failed to engage with science during this period; there was a range of activity, and one only has to look at some of the records set by the RAF and the advances behind these to recognise that research was being undertaken. However, this research might be termed 'tactical' – seeking improvements to aircraft and armaments, rather than looking to science to offer ideas on how more operational problems might be addressed. In adopting this tactical approach, the RAF was perhaps ignoring its early past, specifically the various studies executed by 'Viscount Tiverton', Major Hardinge Goulburn Giffard, who produced the first comprehensive plan for strategic bombing, whilst serving in the Royal Naval Air Service during World War One. While many of these studies focused on specific tactical problems, such as accurate bombing, they showed the way in terms of how science might be brought to bear on operational problems. The scientific approach had also been developed by

various others, including Tizard and Frederick Lindemann, in their work at Martlesham Heath and Farnborough respectively; again though, this work was essentially tactical, focused on improving aircraft and solving specific problems of flight.

This incremental focus is also borne out by review of DSR's quarterly reports on research. These show a strong focus on practical research, each being introduced by a statement that 'These investigations aim at the elucidation of (a) new methods of solving aeronautical problems, and (b) the discovery of the reasons why existing methods of solution sometimes fail; the application of such solutions, from whatever source they may come, to the needs of the service and civilian aviation, is a matter for technical development, and is not therefore dealt with in this report.'[21] The summaries show what the DSR considered in his overview of research in progress. The structure was based on the research establishments and the research is very much focused on practical application of technology. The Air Ministry did fund the Air Ministry Laboratory at Imperial College in South Kensington, but this too demonstrated the strong focus on practical research notable in the DSR's reports.

These quarterly reports do not include any overview of relevant scientific advances or literature to consider their potential usefulness in an RAF context. This lack of a watching brief on wider research was a significant omission in their approach to bringing the best of science to address the RAF's problems. Neither is there mention of the work being carried out at the War Office's Air Defence Experimental Establishment (ADEE) on sound mirrors, an unusual omission given how important this work was to the whole air defence concept. Including a review of progress in the sound mirrors research might have triggered challenges to its progress, and likely utility, earlier than these were actually raised.

Until the creation of the Committee for the Scientific Study of Air Defence (CSSAD) in 1934, the RAF was not organisationally structured to bring science to bear on its more general problems (although Hartcup notes that both the Royal Navy and the Army had, since 1900, set up various civilian committees to provide advice on how science could improve various technologies).[22] Research was 'controlled by competent and conscientious RAF officers who concentrated upon improving the weapons familiar to them' according to AP Rowe, Wimperis' deputy.[23] This was their focus, and no doubt there were more than enough of these problems to occupy them, without any fanciful notions of long range aircraft detection being added to the to-do list. The greater failing, if one is to put it that way, is that there was no effective mechanism in the Air Ministry to frame broad questions for scientific advisers, in such a way, as to encourage them to look widely across science and published research to find solutions to these problems.

This omission continued in the manner that the RAF addressed the problem of early warning. The War Office had experimented with sound mirrors, building on its research into using sound to locate enemy artillery batteries. Two mirrors had been built, one at Fan Holes near South Foreland and one at Joss Gap near North Foreland. These were parabolic reflectors, carved into

chalk cliffs, with subsequent mirrors either carved into cliff faces and given a smooth concrete face or built from reinforced concrete. These symmetrically planed mirrors were a success; 'the Joss Gap mirror … did very good work. It was instrumental in giving warning … before the sounds could be picked up by the ear on the shore.'[24] DSIR noted in July 1919 that aircraft could be heard at seven or eight miles, with the sound being 'very loud' even when 'it is quite inaudible to the unaided ear.'[25] So this was a technology that had been tested under wartime conditions and was assessed as effective.

Research continued after the end of the war in the Acoustical Research Section (ARS), funded by the War Office. In 1929 the ARS was absorbed into the War Office's Air Defence Experimental Establishment (ADEE). Created in 1925, the ADEE was staffed with between 15 and 20 people, making it 'one of the largest military scientific programmes.'[26] The RAF provided test aircraft when requested to support experiments but does not appear to have been involved in this work in the development of this programme in the early 1920s to improve the early warning available through sound mirrors. Despite this in '*Years of Command*', Marshal of the Royal Air Force, Lord Sholto Douglas, stated that '*A great deal of thought was being given even then [i.e. the 1920s] to matters of home defence*.'[27] The French 'scare' of 1923 that prompted the agreement to expand the Home Defence force to 52 squadrons does not seem to have triggered an increased interest and involvement in the Army's work on sound mirrors. Ferris believes that the RAF had a 'powerful' relationship with scientists in the interwar period, with the development of sound mirrors 'showing a willingness to apply science to air defence'.[28] However, it was not the RAF using science to address the question of early warning; it was the War Office; in the 1920s the RAF itself did not appear to have considered whether another, better, approach might be possible.

A broader review of the approach to anti-aircraft defence came from the Anti-aircraft Research Sub-committee, that the Committee for Imperial Defence (CID) had set up under the ARC in May 1925. Its membership included all three Services, and its meeting records show the RAF took this issue seriously. It focused on the tactical question of identifying and then destroying enemy aircraft, and, it considered a range of potential technologies, including acoustical methods, the possibility of tracking aircraft based on the electromagnetic emissions from their engines, and infra-red detection.[29]

The ARC's 1926 report concluded that sound mirrors were the only practical early warning technology, despite their known technical limitations, which had been explored throughout the 1920s. One problem was that the system had to be tuned to specific engines, which presupposed knowledge of the acoustic signature of those engines; 'the exhaust sound of the Hinaidi bombers used in the night raids during the Exercises is quite outside the range of the existing microphones.'[30] The system could also be compromised by early stealth technology; 'The Hinaidi is notably quiet, and has been known to fly over Anti-Artillery troops at 15,000 ft without being detected. Its acoustic output … is only one-fifth of that sent out from a Vickers Virginia.'[31] This was not just an issue for early warning; the War Office was also depending

on sound locators to allow anti-aircraft batteries to target bombers at night, and silencing engines was investigated by the RAF to help make its own bombers harder targets for enemy anti-aircraft guns. Trials with unsilenced and silenced Heyford aircraft in 1935 showed that this technology could reduce warning times by on average five minutes, from circa 11 minutes to circa six minutes.[32] Weather could impact on their performance, with 'wide fluctuations in range caused by weather conditions' being noted.[33] Other sound could also cause problems, with 'jamming by the sound of the propellors of passing ships' being noted on occasions.[34]

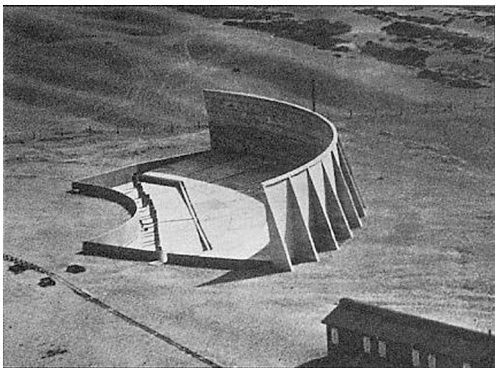
These issues were constantly re-examined to see if solutions could be found; for example, a Signals Experimental Establishment (SEE) – the Acoustical Research Section's parent before the Air Defence Experimental Establishment was set up - report on 27th February 1922 shows that research was being done into the problems caused by rain, fog and mist, and wind.[35] ADEE's summary of 1933 trials makes some of the problems with this technology clear.[36] The War Office's own manuals also noted that the effectiveness of sound location depended on the aspect of the aircraft; 'if the machine is end-on (receding or approaching) the sound of the airscrew [a key component of the sound to be detected] cannot be heard.'[37] Incremental improvements were made to the technology over time, with 'mean maximum of 22.1 miles, as compared with that obtained at the earlier trials [ADEE report 62, October 1931] of 16¾ miles' in the July 1933 trials.[38]

This work was aimed at addressing the limitations of sound mirrors. Radio-based detection from the ground, (what would become radar), was not considered in either in the ARC's 1926 report or later; although the Memorandum ARC Paper No. 43 contains the tantalising phrase that 'It is therefore possible that a method of location [of aircraft] … by secondary excitation in a strong field emitted by a ground transmitter…' – but this was taken no further.[39] Between 1925-26 the ARC Sub-committee also considered whether the detection range could be increased by stationing observers offshore but discounted this proposal as ineffective. In November 1934 the ADEE reported that listening ranges would not significantly improve.[40] Furthermore, DSR concluded that 'performance is not sufficiently good to make trawler-listening of practical utility', and the Royal Navy had concluded that problems of station keeping and vulnerability to attack would make this solution impractical.[41]

War Office reports on progress with the mirrors were copied to the Air Ministry so that the Air Ministry was aware of the work being done, and its potential limitations, from the outset. Despite these issues, the RAF continued to look to sound mirrors to provide the early warning it needed throughout the 1920s and into the 1930s, alternate programmes championed by the RAF failed to emerge. Why this might be the case is discussed below; DSR did not initiate any research programmes in this area though until the creation of the Committee for Scientific Survey in Air Defence (CSSAD) in 1934.

There was an early appreciation of the potential limitations of the technology, and ranges were not expected to be huge; 'the 20ft and 30ft mirrors are designed to give warning and sound

bearings at ranges up to 10 miles, and the 200ft mirror to give warning and bearings at ranges up to 25 miles.'[42] Construction of the larger sound mirror at Denge, near Dungeness, began in 1928 and was completed by July 1930. This was the ultimate expression of sound mirror technology, 200ft long and 25ft feet high, the longer wavelengths it sought to detect did not need the full parabolic mirror. It sat alongside the 20ft and 30ft mirrors that provided more accurate data on incoming raids once the larger mirror had detected the raid. Such a large mirror was needed 'because the most penetrating sounds for long distance transmission' could only be detected by the larger mirror, using microphones rather than the human ear.[43]



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http://www.andrewgrantham.co.uk/soundmirrors/locations/denge/

Despite all the known issues with the technology, given aircraft speeds and altitudes in the 1920s, a warning of up to 25 miles was helpful. Air Vice-Marshal J Salmond, AOC-in-C Air Defence of Great Britain (ADGB) stated in 1925 that if aircraft could be detected at 15 instead of 10 miles this 'would be of considerable value to the air defence of the country.'[44] The RAF's requirements for early warning were defined in November 1925 as being detecting aircraft at a range of 25 miles from the coast, with height, speed, course and number of aircraft being detected at 10 miles range – so the sound mirrors met the RAF's requirements at the time.[45]

In 1926 the Air Ministry began to contribute to funding the early warning programme, stating in December that the programme was 'fundamental to the scheme of defence.'[46] Despite this, not all were convinced the RAF should contribute. In '*Echoes from the Sky*' Richard Scarth notes the Chief of the Air Staff (CAS), Air Chief Marshal Trenchard, expressing alarm on 23 March 1928 that the RAF should be asked to fund work 'which relieves the other services of their legitimate responsibilities.'[47] This is likely to be more indicative of inter-Service budget battles, rather than CAS objecting to the technology per se.

By the early 1930s the RAF was considering testing the early warning technology in the annual Air Exercises. These Air Exercises were the main, albeit limited, opportunity to test all the components of the air defence system simultaneously, including new technology and tactics. To this end, the sound mirrors were included in the 1933 Air Exercises, and AOC-in-C ADGB, Air

Marshal G Salmond's Report on the 1933 Air Exercises said that 'the information was of definite value.'[48] The mirrors continued to be incorporated into the Air Exercises, being tested again in 1934 when 'little or no use of the early warning' was possible due to other aircraft movements, a problem that was never resolved.[49] They also appeared in the 1935 Exercises, a final flourish given the AOC's comment that their range 'is not great enough in the case of a really fast moving enemy'.[50] However, this was the best technology available, and the results of the trials in the 1933 Air Exercises had been encouraging enough for ADGB to propose in November 1933 'a scheme for the employment of a number of 200ft strip mirrors and 30ft bowl mirrors to provide a continuous warning screen from the south-east of England from the Wash to St. Albans Head.'[51] This proposal could not be fully funded so 'Air Marshal Salmond had therefore asked that the mirror system should be provided to cover the Thames Estuary.'[52] The aim was to have these mirrors built and operational in time for the 1935 Air Exercises.

However, the scheme stalled and it was not until 17 December 1934 the Air Council told AOC-in-C ADGB that the mirrors for the Thames Estuary part of the scheme had been approved.[53] The Thames Estuary scheme progressed through 1935, with significant resources being earmarked for it, demonstrating the seriousness attached to early warning by the RAF.[54] However, on 15 August 1935, the project was suspended by the incoming AOC-in-C, Air Marshal Steel, possibly because of the promise shown by the early Radio Direction Finding experiments. In January 1936, CSSAD's survey of air defence noted the scheme was 'in abeyance pending the results of RDF location.'[55] The idea of building mirrors in Singapore and Hong Kong was also raised in 1935, but it was concluded that the 3¾ minutes of additional warning they would give the RAF at Singapore meant 'acoustical mirrors would be of no value.'[56]

The withdrawal of RAF support for sound mirrors in late 1934-35 was understandable. By November 1934 the warning time provided by sound mirror technology was unable to meet the RAF's requirements, which had evolved and were being expressed as a requirement for a 16 minute warning, made up of five minutes to recognise the raid and launch fighters in response, and 11 minutes for them to then get to an interception height of 20,000'.[57] This translated into a requirement for a warning range of 70 miles, assuming bombers flying at 250 mph. This demonstrates sound mirror technology had been overtaken, by the increased speed of the attacking aircraft, in terms of their ability to provide adequate warning.

During the 1930s, the RAF realised the need to improve early warning as aircraft speeds and altitudes increased significantly, which resulted in the trials of broader solutions. The 1932 Air Exercises included the use of an 'aircraft observation patrol,' which had been utilised in the First World War.[58] These patrol aircraft tried to spot incoming raids and shadow them while providing information on the raid to ADGB, a variant of which was tried in the 1930 Exercises.[59] AOC Fighting Area's conclusion in 1932 was that 'There is as yet insufficient experience to judge whether reconnaissance aircraft are of any assistance for detecting raids.'[60] AOC-in-C ADGB, Air Marshal G Salmond was more positive, believing that 'development is justified.'[61]

The 1933 Exercises concluded that 'these patrols are of considerable value.'[62] In the 1934 Air Exercises AOC-in-C ADGB, Air Marshal Brooke-Popham, concluded that 'they hold out the prospect of giving valuable early warning.'[63] However, after the 1935 Air Exercises the next AOC-in-C ADGB, Air Marshal Steel had a different view, saying 'I feel that there are more efficient and less wasteful methods of achieving the same object [earlier warning of raids].'[64] He did not specify these; it is possible that he had an early awareness of the work that had already begun around RDF.

These attempts to improve early warning show those RAF leaders charged with defending the UK appreciated the importance of early warning to an air defence system. They continued to look at a range of approaches to address this problem, as befitted a Service that prided itself on its technical capabilities. While, with hindsight, sound mirrors can be seen to have been a dead end, their pursuit as a technology that could offer earlier detection of incoming aircraft and hence address a key problem of air defence was entirely rational at the time; in '*Tucker's Acoustical Mirrors*' David Zimmerman is overstating the case in describing sound mirrors as 'a case study of everything that can go wrong in a military scientific development programme'.[65] What is true is that by 1935, when the Air Ministry withdrew funding from the programme, increased aircraft speeds and altitudes meant that detection at ranges of 70 miles or more was needed and sound mirrors could never have achieved this.

However, as the shortcomings of sound mirrors became evident, the RAF's approach to science meant alternatives were not identified. There was no expectation that DSR or any other Air Ministry or government body such as DSIR would look to basic science to identify possible solutions to this pressing operational problem. Until the creation of CSSAD, the RAF did not create a research agenda or approach that called on science as a source of new ideas or technologies, to address fundamental problems, including early warning. In contrast, in the Royal Navy's case, the invention of ASDIC, a sonar system to detect submerged submarines, had shown how science could help solve fundamental problems. Zimmerman notes that 'the armed forces tended to see its scientists as being the producers of gadgets.'[66] This mindset meant many scientists saw military work as 'essentially second rate and dull,' which hardly encouraged them to work with the military.[67] There was also limited funding available, and an understandable inclination to spend it on work that might have practical, and more immediate, benefits. Thus, DSR's quarterly reports show the limited funding for university researchers being directed to specific aeronautical problems, rather than broader innovative enquiries.

Essentially, there was a lack of any science-based approach to solving broader problems in the RAF, even though scientists had done work that might have been developed to provide better early warning. This work was either overseas (e.g. Hülsmeyer), relatively theoretical (e.g. Marconi), done by the Royal Navy or Army, or outside the military realm (e.g. the Post Office papers noting the effects of passing aircraft on radio transmissions). One possible explanation why investigation into radar was not developed may be that those with the knowledge of

this concept rejected it because they believed the wood and fabric structure aircraft of the time would not provide a strong enough echo to make radar useful.[68] Wilkins notes that such an aircraft was used for tests in 1935 to see if it could be detected by RDF, and the 'range for detection was about halved.'[69] However, if the technology was consciously discounted for this reason, no trace exists in the records, while other ideas for detecting aircraft, such as radiation emitted by magnets, was considered even when it was known this was unlikely to work.[70]

Where the RAF and Air Ministry perhaps fell short was that they failed to identify the technology which would later develop into radar, as a viable, alternative solution to the early warning problem; Zimmerman saying 'little or no effort had been made to call on science to find a way out.'[71] This failure to identify radio as a promising solution is not solely their fault; the two CID Sub Committees on Anti-aircraft Defence had also failed to consider this approach, while considering a range of other technologies and rejecting them. Brown believes that information about the various experiments described above 'must have spread widely and informally' among researchers, but the Air Ministry and RAF lacked the contacts with such networks.[72] Watson-Watt talks of 'the wide open tool-box of ideas from which the weapon of radar might be forged' when surveying the scientific work done before his practical work leading to radar; the question is why this 'tool-box' did not lead to radar earlier.[73] This is echoed by AF Wilkins, who notes the effects described to him by Post Office engineers on aircraft disrupting VHF transmissions in 1930-31, but he, the Post Office, and the Radio Department at RAE 'failed to look further into the matter,' probably because sound mirrors were the approved solution.[74] In the Air Ministry files one can occasionally find mentions of interesting experiments overseas, but there was no systematic way to identify and assess those which may have been of interest.[75] The idea of a 'literature search' was recognised in the Air Ministry: in October 1923 a committee created to study defence against pilotless aircraft looked in patents to understand how such aircraft might be controlled.[76] However, there is no evidence that this approach was used to for solutions to the early warning problem.

The bigger question is why the RAF did not do more to directly fund or pursue 'blue sky' thinking into the challenge of early warning. In February 1935 radar was developed in the UK thanks to Watson-Watt and AF Wilkins, who investigated further the work initiated by Wimperis, whilst answering his question about the feasibility of 'death rays', to show that radio detection of aircraft was technically possible. The failure to identify radio-based technologies as a possible solution to the early warning problem thus lies with the way the RAF had defined the role of the DSR (which excluded radio matters) and the broader failure to link science with the RAF's most pressing problems.

CSSAD was the RAF's first attempt to look to science for solutions to its most pressing problems, and its terms of reference required it to 'consider how far recent advances in scientific and technical knowledge can be used to strengthen the present methods of defence against hostile aircraft.'[77] These terms of reference, drafted by Wimperis, were much more wide-ranging than those given to the previously described committees. Through these

terms CSSAD was invited to start from first principles and thus saw the first effective attempt by the RAF to bring civilian science to bear on its critical problems. However, even once RDF was under development, some believe the RAF failed to call on the 'best and brightest' to drive the concept forwards. Brown notes the failure of the Air Ministry's to identify and call upon the best civilian technology and people (citing EMI's television research team that included nine relevant PhDs) as the Chain Home system was built.[78] Given the speed with which the Chain Home stations were commissioned, it is hard to see this as having significantly slowed the project down.

Britain was not the only country that suddenly saw radar development take off in the mid-1930s. Many countries took radar research seriously from this time, including France, Italy and the Netherlands, as well as the 'usual suspects' of Britain and Germany.[79] Brown suggests that this may be partly because various scientific researches and advances in technology came together at this time to make radar a more practical technology. The question is whether this research could have been accelerated had the funds devoted to sound mirrors instead been focused on research into what became radar. There are understandable reasons why this did not happen, including, perhaps, the importance placed on air defence by the RAF; stopping development of an established technology (sound mirrors), that during the 1920s offered some benefits, to work on a non-existent technology that theoretically could be developed to a point where it would offer significantly greater benefits, would have been a brave step. It took the increasing aircraft speeds in the 1930s to make sound mirrors obviously obsolete; before that, they could still provide 'information … of definite value.'[80]

It is likely that organisational inertia also came into play; a programme was in place, was funded, was proceeding; such things often acquire a life of their own. However, the programme was owned by the War Office, whose need for effective long-range early warning was not as great as the RAF's. This may be why the RAF so swiftly withdrew support from sound mirrors once RDF began to look feasible; having gained initial assurance that RDF was viable, and could be delivered quickly, they focused resources on RDF rather than sound mirrors.

Perhaps one explanation why the RAF did not pursue radar earlier is the background of the scientific advisers; had DSR not been a mechanical engineer and had he spent less time on combustion investigation and more on radio investigation, radar might have emerged earlier. Furthermore, had DSR's remit not specifically excluded radio research, Watson-Watt's 'tool-box' might have been opened and used earlier.

AP Rowe acknowledges that the theory behind radar was well enough known, but states that the 'catalytic agent was a request from a defence department concerned with the destruction of hostile aircraft.'[81] Bowen, one of the other early British pioneers, praised Swords' book, saying it 'finally gives the lie to Watson-Watt's claim to have invented everything.'[82] But the earlier development of radar must remain an interesting 'what if' since it did not

happen, and given Britain as a nation had not really properly worked out how to use science to solve applied problems faced by government (DSIR being a new creation in the 1920s), to expect such a step forward is probably unreasonable.

Notes

[1] Robertson to Haig, 15 June 1917, Robertson Papers, 1/23 Liddell Hart centre for Military Archives, cited in J Ferris, 'Airbandit': C3I and Strategic Air Defence, 1915-18, p. 41, in M Dockrill and D French, *Strategy and Intelligence: British Policy during the First World War*, (London, Hambledon Press, 1996).
[2] MRAF Sir H Dowding, *The Battle of Britain*, (London, The London Gazette, 11th September 1948), Para. 54.
[3] Pritchard, *The Radar War: Germany's Pioneering Achievement 1904-45*, (Wellingborough, Patrick Stephens Limited, 1989), p. 7.
[4] G Marconi, *Radio telegraphy*, (London, Proceedings of the Institute of Radio Engineers, Vol. 10, Issue 4, August 1922), pp. 215-238.
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[64] AIR 20/184 Report on the 1935 Air Exercises, 25th November 1935, para 140.
[65] Zimmerman, *Tucker's Acoustical Mirrors*, p. 73.
[66] Zimmerman, *Britain's Shield*, p. 58.
[67] Zimmerman, *Britain's Shield*, p. 58.
[68] As a historian, I lack the scientific skills to know if this is true; however, I make the statement based on independent discussions with Richard May and Niall McConville, holders of MScs in Physics from Oxford and Cambridge respectively, who I am confident know what they are talking about in agreeing with this statement.
[69] Kinsey, *Orfordness*, p. 148.
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[76] AIR 5/487 Defence against Pilotless Aircraft, Minutes of First Conference, 24th October 1923, para. 2g.
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[79] See the many chapters in Burns, *Radar Development*, outlining these various developments.
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