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THE ROLE OF RADAR IN AIR DEFENCE

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The story of Radar, for obvious reasons, was a closely guarded secret during the last war, but since the end of the war, news papers and magazines have published a large variety of articles on its achievements in World War II. Of late, several books have also appeared on the subject of Radar. I am sure that you all, gentlemen, would have come across some or most of these and therefore, what I am going to say may appear to some of you as retelling an old story. However, as one who was familiar with the science of Radar from its early days and who has had occasion to play a humble part in its achievements in South East Asia, I hope I shall make bold to speak to you as one with first hand experience.

2. The word 'RADAR' is a manufactured term, its full form being "Radio detection and ranging" and was first used by the Americans. The British equivalent was Radio Location or Radio Direction Finding, R.D.F. for short. When America joined the war on the side of the Allies, the word Radar was universally accepted.

3. The time and place of the origin of Radar are controversial points. I do not wish to enter into the controversy as it is outside the scope of this conference. Suffice it to say that Radar has played a very important part in the last war and that it has been a major factor in changing the course of events. I don't think that I can describe its importance better than by quoting what two eminent British personalities have stated about its achievements. In the words of Sir Stafford Cripps, the war time president of the Radio Board,

> "It has played a greater part in the war than the atom bomb and holds far more potentialities of service to the human race than the splitting of the atom".

Describing how Radar helped in the interception of German and Italian raiders over Malta, Air Chief Marshal Lord Tedder said,

> "It was unforgettable to be down in the operations room in Malta, watching the enemy taking off from his airfields, assembling, noting how they were approaching and then see our fighters being guided to intercept them".

4. I am sure you all know that the basic principle of Radar is the property of radio waves to get reflected from material objects. Direction and distance finding by the use of echoes is by no means new. The process has been in continual use ever since some savage in his bark canoe shouted and listened for the echo from a nearby cliff. It has been demonstrated that bats emit short bursts of supersonic energy as a means of detecting and ranging on objects. Modern science has used this principle for under water ranging.

5. In all these systems, a short sharp pulse of energy is emitted, it travels to the target, is reflected and travels back again. By listen-

ing to the echo the direction of the target and its distance can be estimated, the latter from the known velocity of the energy.

6. However, considering that the velocity of sound in air is approximately 1,100 ft. per second, a modern plane travelling in excess of 300 miles per hour or 450 feet per second, will be out of range before any effective action could be taken against it, if a sound system of warning were relied upon.

7. On account of the shortcomings of the older types of detection methods, it is obvious that the modern system must have a sufficient range to be effective against aircraft, must be equally efficient day or night or in cloudy weather, must possess a high degree of accuracy and must be capable of being used on land, at sea or in the air. The Radar system is designed to meet these requirements and consists of—(1) a source of powerful R.F. pulses of short duration, i.e., a transmitter and a directional radiator, (2) a receiver of great sensitivity and (3) a means of indicating the required data. The discovery of this principle dates back to the early days of radio when it was discovered that the ionosphere was reflecting radio waves and thereby the height of this layer could be measured.

8. The fact that radio waves possessed optical properties was demonstrated as long ago as 1886 by the famous experiments of Heinritz Hertz, the discoverer of radio waves. Hertz showed, among other things, that radio waves were reflected from solid objects. In 1904 a German Engineer was granted a patent in several countries on a proposed way of using this property in an obstacle detector and navigational aid for ships. In 1922, Marconi strongly urged the use of short waves for radio detection. Successful detection devices were developed independently in America, England, France and Germany during the thirties. British radar was developed at a faster pace than that of other countries under the immediate threat to Britain's security. During the winter of 1934-35, the Air Ministry set up a committee for the scientific survey of air defence. Among the suggestions it received was a carefully worked out plan for the detection of aircraft by a pulse method, submitted by a Scottish scientist, now Sir Robert Watson-Watt, who was then the head of the National Physical Laboratory Radio Department. The first experimental system was set up in the spring of 1935 on a small island off the east coast of England. By March 1938, five stations about 25 miles apart were set up to protect the Thames estuary and started operating under R.A.F. personnel.

9. *How Radar Works.*—Let us now see how radar works. As you all know, Radar, like communications, consists of a transmitter and receiver, but unlike communications, the Transmitter and receiver are both located at the same place and have very often a common aerial. The transmitter send out energy in intense bursts or pulses of extremely short duration of a few micro-seconds. After each pulse, the transmitter shuts down for a relatively long time, during which the receiver is functioning and the signals it receives are the echoes of the powerful transmitted pulse, from nearly objects. The nearer objects give echoes sooner than the more distant ones. The time elapsed between the transmission of the pulse and the return of the echo gives a measure of the distance of the target, exactly as in sound detectors.

This is rendered possible by our knowledge of the velocity of electromagnetic waves namely 186,000 miles per second or 328 yards per microsecond.

10. *Bearing.*—In order to define the exact position of an aircraft in space, we have to determine three factors. Distance or range is only one of them and we have seen how pulse technique enables us to determine this. The second dimension required is the direction or bearing of the target. This is measured by providing the radar with a directional aerial system which sends out the pulses in a narrow beam like a torch light. The aerial may be rotated and we get back an echo when the antenna is pointed towards its target. The bearing of the antenna, which can be read off on a circular scale, gives the bearing of the aircraft.

11. *Height.*—There is yet a third factor to be determined and that is the angle of elevation of the target or its height above ground. This is also determined by the directional property of the radar aerial and of its being capable of rotating in a vertical plane until the echo has maximum strength. The height above ground can be computed from the known values of slant range and angle of elevation.

12. *P.P.I.*—A more spectacular indication of the direction and range of a target are obtained by the use of a cathode ray tube as a P.P.I. or Plan Position Indicator. In this case the Radar echoes are made to cause intensity modulation and thereby draw a map on the face of the tube of objects surrounding the Radar set up to a distance of 50 or 100 miles. No matter how many objects surround the Radar set, each is indicated by a blob of light, the intensity of which varies with the amount of energy reflected by it. The whole picture is there, with the Radar set occupying the centre and ranges and bearings can be read off from a range scale and degrees marked along the edge of the tube face.

13. *Britain's Radar Defence.*—The mass assaults on England by the Luftwaffe began early in *September,* 1940 and rapidly increased in intensity and with that the defensive chains opened four years previously had their first great test. Despite a critical shortage of fighter planes and pilots, the R.A.F. was able to spot each incoming raid in time to throw fighters against it. The necessity for constant airborne patrols of fighters was eliminated by the use of Radar and "the few to whom so many owed so much", to quote Churchill's phrase, were thrown into battle economically and with the maximum striking power.

14. *A.I. & A.S.V.*—By *November* that year German tactics had changed and the day raids were replaced by night attacks. These night attacks increasingly put the reliance of the defender on Radar. Not only was visual spotting more difficult, but the defending fighters encountered such poor visibility that Radar aid for the fighter pilot became a pressing need. The emphasis on British Radar development, then, shifted to airborne equipment. Two types were envisaged, a set for the detection of enemy aircraft from night fighters called A.I. (for Aircraft Interception) and another for the detection of surface vessels, called A.S.V. The emphasis on airborne radar led to the observation that if sharp radar beams were ever to be produced by an aerial not too large to carry in an aeroplane, wavelengths shorter than 1.5

meters would have to be employed. At 1.5 meters conventional transmitting valves were adequate to generate the required pulse power; but no powerful oscillator capable of generating waves much shorter was known. Consequently, the problem of developing a microwave generator was given to a research group in the University of Birmingham. With the co-operation of the British industry, the Birmingham group developed a practical form of the cavity magnetron. This, along with other developments opened the possibility of obtaining satisfactory power output at centimetre wavelengths, leading to the enormous widening of the power of Radar after 1940.

15. *G.C.I.*—In addition to the development of A.I. Radar, a new technique known as G.C.I. was also evolved to counter the German night raids. During the day raids, it had been sufficient to bring the fighters into the general vicinity of the enemy raiders and rely on each pilot's vision and judgment or choosing targets and making interceptions. At night, this was no longer possible. In the G.C.I. technique, a controller on the ground, watching the air situation on the P.P.I. of a special radar set, chooses a special enemy plane as a target, gives detailed course instructions, which we call 'vectors' to the fighter under his control and skilfully manouvers the fighter to a position 1 to 3 miles behind the target, just below and on the same course. When this is done, the fighter is asked to "flash his weapon" and the A.I. radar in the fighter takes over. This was operated by a special radar operator who had no other duties and the pilot was only a chauffeur obeying instructions right upto the moment when he was close to the enemy plane to see it against the night sky. From this time on, the pilot completed the attack.

I would like to add that this complicated technique demanded team work of a very high order between ground controller and pilot and between A.I. operator and pilot.

16. *I.F.F.*—There was one other technical device which completed the success of this complicated technical system. This was a device known as I.F.F. (Identification, Friend or Foe). I.F.F. is a small radar set fitted to all our aircraft and which is capable of giving an identifying signal to a ground radar station or a fighter plane, when interrogated by it. This helped the radar station or the fighter to distinguish between friend and foe as soon as they were picked up on his tube.

17. *A.A.*—There is another department of air defence in which radar has played an important role, namely A.A. gun laying. Modern aircraft fly so fast that the antiquated method of locating them by sound detectors, search-lights and tracking telescopes is as complicated as it is inaccurate. Modern anti-aircraft radar locates planes most accurately and in addition once the plane is caught in the beam of the A.A. radar, by automatic remote control, points the gun always at the target and enables it to follow its movements.

This device was of great service during the flying Bomb raids over England. The accuracy of the A.A. radar defence will be illustrated by the fact that on 21*st* August '43, although 105 of these pilotless planes or Buzz Bombs as they were called, crossed the British coast, for London, only 3 of them arrived!

18. *Battle against U-Boats.*—Though the subject of my talk is role of radar in air defence, I think it will not be out of place if I touch on another important part played by radar in the last war, namely the battle against U-boats.

From the beginning of World War II, the Germans had decided to put a major effort into the destruction of allied shipping by concentrated U-boat attack. Consequently, the Allies spared no efforts to remove this menace from the sealanes of the Atlantic. The battle against the U-boat was, in fact, a technical conflict, with thrust, counter thrust and parry, all being executed in terms of new devices and technique. During 1942, U-boats were sinking allied shipping at the rate of 16,000 tons per day.

As I have stated earlier, the British had already developed a radar known as A.S.V. for the detection of submarines or other vessels on the surface. These were fitted to long range aircraft and the sea lanes where U-boats were known to be working were constantly swept by the radar beam. As soon as the echo of a surface vessel was observed on the cathode ray tube, the aircraft changed its course, headed straight for it and attacked it before it had time to sub-merge.

The early A S V equipment were rather crude and of limited range. But soon research development evolved sets working on shorter wavelengths and of longer range. As the rate of loss of submarines mounted, it became apparent to the Germans that the aircraft attack on their U-boats were taking place far too often to be the result of complete reliance on visual sighting. They suspected radar and after capturing one A S V set, they fitted receiver to U-boats to warn them of approaching aircraft. The allies replied by mounting microwave A S V equipment in their aircraft, which, the submarine receivers were not capable of detecting. Again, the U-boat kills increased and the menace was removed.

Radar as an offensive weapon.

19. H2S.—In the early days of World War II, radar was looked upon and utilised as a weapon of defence and utilised as such. But later years proved its possibilities as an offensive weapon. When the initiative of aerial warfare passed from the Nazis into the hands of the allies, they decided to commit their heavy Bomber force to night operations entirely. They knew that night operations would be successful only if good aids to navigation and special means for target location were provided for every aircraft. Scientists at T.R.E. worked feverishly day and night to evolve a self sufficient radar that could be fitted to each Bomber and which could find its way and identify its targets totally blindly. A new type of microwave radar known as H2S was developed, at first by modifying an A.I. equipment. It was already known that with a centimetre A.S.V. equipment, a map of the sea could be displayed on a P.P.I. tube and that any surface vessel in its field would show off clearly against the background of sea returns. There was therefore, good reason to suppose that if the A.S.V. radar beam was used to scan land, better radar echoes would be got from the smooth walls and roofs of buildings than from irregular surfaces offered by woods and fields. This was tried and it was found that strong indications of towns were seen on the cathode ray screen. This was H2S born. Shortly afterwards, flights were carried out over

cloud in which photographs were taken of the P.P.I. presentation of certain towns. These proved highly successful. There was great silent jubilation following this discovery and the general feeling that a turning point in the war had been reached filled the minds of the few who knew about it. The discovery was of invaluable help to the Bomber aircraft because of what it offered to the navigator. He had, now, before him a screen on which, whatever the thickness of the clouds below him or the blackness of the night, and however far from home, he could distinguish between land and water areas, see the shape of the coast line and the picture of townships as he flew over them. After the war, the British press described H2S as the 'Magic Eye', but there was no magic about it. When the sweeping centimetre beam of an aircraft radar strikes water obliquely it is mostly reflected away from the aircraft and so water shows up as a dark area on the H2S screen. When the beam strikes ordinary country side such as wooded areas and grass land, the energy in the beam is scattered by the irregular surface and some of it comes back to the aircraft and illuminates that area of the screen which corresponds to the land area. It sounds simple, but a quarter of a ton of complicated equipment had to be evolved and installed in every aircraft before H2S could be used for attacking Germany.

20. There were other developments also, embodying pulse technique, which served as aids to navigation, such as Gee, Oboe, Loran, Rebecca, Eureka, Babs and so on. Though these are less spectacular than the ones I have described, they are all the same, of invaluable help to navigation and bombing of military and civil aircraft. New developments are adding greater and greater safety to air travel.

In conclusion, let me thank you gentlemen for bearing with me for the last few minutes and express the hope that this conference will pave the way to organizing research and development in the sphere of radar speedily so that our armed forces may not have to depend on foreign aid for their weapons for long.