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Item Description: This is a draft manuscript of a lengthy report compiled by the RAF Bomber Command Operational Research Section, probably some time in 1945. The report was authored by Dr. Basil Dickins, a rising star in the field of physics who served as Section head during the war. Using a thematic approach it explores in excellent detail the challenges inherent in strategic bombing, making it a valuable source for both historians of air power and those studying Europe in the Second World War.

Keywords: Bomber Command; Operational Research; Operations; Technique; Bombing; Navigation

CHAPTER 17

RADIO AIDS TO THE DEFENCE OF BOMBERS

The Scope of Radio Aids

The first year of the European War demonstrated to Britain the great value of radar as a defensive weapon. Photographic reconnaissance and listening watches revealed that the enemy had also realised the possibilities of radar aided defence and therefore, when it became possible to prepare an air offensive, thought naturally turned to means of neutralising the enemy's radar system and to applying radar searching methods to the protection of bombers.

During 1941 the enemy was still capable of substantial bombing raids against this country and there was great reluctance to take determined action against enemy radar lest retaliatory action should inflict a serious handicap on our own defences. In 1942, the relative power of offensive action in the air swung decidedly into this country's favour and a campaign of radio-countermeasures began. This gathered strength with the progress of the air/war and, changing in its direction of incidence in order to meet enemy developments, continued, to the end of the war.

The aim of the radio-countermeasures was to deny to the enemy radar installations the information which they sought and to prevent the passing of information by wireless means. In addition, during 1943, radar search apparatus was fitted into bombers, in order to provide aircrews with warning of imminent hostile action against them, and into fighters used for bomber support. Radio aids provided specifically as aids to navigation could also clearly have an effect on the defence of bombers since they could assist in maintaining the high concentration of bombers in space and time which was shown to be a powerful tactical countermeasure against the enemy defences (Bomber Command O.R.S. Reports Nos. 9[1] and 34[2]).

Steps in the Development of a Radio Aid

In the introduction of radio aids for bomber defence the normal chain of development may be stated as follows.

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(a) The provision of knowledge of the enemy's defensive system and of technical details of his radio and radar installations.

(b) Decisions of policy as to the parts of the enemy's system to be assailed.

(c) Technical development of the means to carry out the policy.

(d) Decision of what scale the effort should be and how it should be applied.

(e) Assessment of the results obtained by application of the measure.

These steps have not always followed the chronological order in which they are set down here, and frequently one step has not been clearly separated from another, but in one way or another all had to be made for each radio aid. Much of the contribution of O.R.S. to the various processes of development will emerge as detailed consideration is given to individual aids, but some broad generalities are more conveniently treated here.

Information about the Enemy's System of Defence

Obtaining knowledge of the enemy's system ~~must~~ was largely ~~be~~ an Intelligence responsibility. There were, however, opportunities for the O.R.S. to assist in some matters since from time to time useful information could be obtained from the observations of aircrew recorded either in their routine reports of operational flights or in special reports requested for a specific purpose. These reports, often appreciated cursorily by Intelligence, frequently required careful analysis to yield their full and true results and this analysis was an appropriate O.R.S. function. An important example of this work which had a strong bearing on the determination of which radio aids offered the highest returns was the assessment of the relative contributions of the various causes of loss of bombers to the total wastage (e.g. Bomber Command O.R.S. Report No. S.91 - 'Night Bomber losses on German Targets 1942').(1)

Design of Equipment

The design of apparatus was a matter entirely for the appropriate experimental establishments, T.R.E. and R.A.E. The O.R.S., however, performed a liaison duty interpreting difficulties in designing to the service and advising the experimental establishments on the expected conditions of operation.

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(1) A.H.B./II/39/1/4.

Direction of Policy

In decisions of policy, concerning either general lines of progress or the scale and mode of application of a particular measure, the O.R.S. almost invariably had a part to play. Most of these decisions had to be based on an incomplete knowledge and frequently had to take into consideration that a device designed to confer a benefit might also have harmful effects. For example, it was extremely difficult to assess the benefit of an electrical airborne jammer for a type of enemy radar set because of uncertain knowledge of the enemy's reliance on that particular set, and the unknown risk that the enemy would use the jamming signal as a means of detecting and destroying its source. Therefore, decisions had to be based on judgments arrived at after full discussion.

Within Bomber Command, the responsibility for recommending action in the field of radio aids rested with the Signals branch, and the O.R.S. maintained a close liaison with the section of that branch dealing with radio-countermeasures. Discussions with T.R.E. either jointly with members of the Signals branch or alone also played an important part in arriving at sound judgments. Apart from these informal discussions on a day-to-day basis, more general consultations were pursued within a Radio-Countermeasure Committee set up within Bomber Command during 1943. This body comprised representatives of the Signals, Intelligence and O.R.S. branches with representatives of the Air Staff and of Air Ministry as occasion demanded. At the time of most active development of countermeasures that Committee met fortnightly. A similar Committee on Tail-Warning Devices (the radar sets carried by bombers to warn crew of the approach of other aircraft) was set up during 1944.

The special role of the O.R.S. in these discussions, in addition to putting ideas into the common pool and presenting assessments of the results of measures already in operation, was to present the facts gathered from all sources in a clear and balanced form so that the issues to be judged could readily be appreciated. This might be done verbally, but occasionally appreciations of the evidence were prepared in writing for discussion or, after the discussion, the conclusions arrived at with the evidence on which they were based were marshalled into convincing form

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for submission to the Air Staff or to Air Ministry. In considering the reports which follow on the work of O.R.S. on individual radio aids, this background of discussion must be borne in mind. Although an attempt has been made to make clear the specific O.R.S. contribution, some of the ideas and judgments referred to were inspired or coloured by discussion with other branches, while at the same time O.R.S. consultation helped in arriving at conclusions which are not included as O.R.S. contributions.

In addition to the deliberations within Bomber Command and at T.R.E., the O.R.S. was represented on the committees at Air Ministry, usually under the chairmanship of the Controller of Communications, which considered the development of radio equipment often in relation to its production. Owing to the difficulties experienced by production in meeting the rapidly changing demands made by radio-countermeasures, these committees had not infrequently to make decisions which involved the Command's policy and, on these occasions, the O.R.S. was able to assist the Signals branch in stating a case.

Assessment of Results

The assessment of the results obtained by radio aids to bomber defence devolved almost wholly upon the O.R.S. For some measures, e.g. the application of jamming to some of the enemy's methods of communication, some effect was made apparent immediately by the enemy's avoiding action. In general, however, the detailed analysis of a large mass of information was required. The methods used and difficulties involved in the assessment will be described before detailed results of each class of countermeasure are considered. It may be said here that these difficulties were such that the conclusions, as has also been stated, had to be based on judgment of indications rather than on incontrovertible facts.

When in December 1943, No. 100 Group was formed in order to operate those of the countermeasures better applied by specialist aircraft, an O.R.S. representative was attached to the Group. He was able to pay special attention to the day-to-day problems of the Group while maintaining close liaison with the general investigations carried on at Command.

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Early Developments

The history of Bomber Command's radio-countermeasures has been dealt with in great detail elsewhere (Air Staff Operational Monograph No. 1 'Countermeasures to German Radar Defences'[1]. The Director of Air Tactics First Draft, May 1944 'War in the Ether - Europe 1939/45 - Radio-Countermeasures in Bomber Command'[2] - Signals Branch Headquarters Bomber Command June 1945). The most convenient method in dealing with the O.R.S. contribution is to consider individually each device used so that its development from conception to demise or honourable retirement can be followed. It is, however, desirable to give a brief account of the enemy's defensive system in order that the functions of the special devices may be appreciated and to review the period before the introduction of specific measures.

At the request of the Air Officer Commanding-in-Chief Bomber Command in September 1941, the O.R.S. prepared an appreciation of the existing knowledge of enemy radar installations and of the proposals for countering them which were being developed (Report No. 4 ' Enemy R.D.F. and Bomber Command Night Operations'[3]). It was pointed out that there was a serious deficiency in our knowledge of the enemy's use of radar in controlling guns, searchlights and fighters, countermeasures against which were considered to be more than necessary than against the better known enemy early warning radar. In forwarding the report to Air Ministry, the Commander-in-Chief requested that immediate further measures be taken to obtain more information on the lines which it suggested. The reply gave an assurance that the search for information on enemy methods and the development of countermeasures would be actively pursued. During the next few months much

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additional information was obtained. The means to secure it included a Commando raid on the enemy-occupied coast in order to capture a Wurzburg, the apparatus used to control anti-aircraft fire. Although there was still some anxiety about the initiation of a jamming war, development of means to counter enemy equipment was actively pursued at T.R.E. as details of the equipment became known.

As this activity brought the large-scale application of radio-countermeasures nearer to practicability, it became necessary to secure a firm policy in favour of a jamming campaign and to re-assess the priority of application. A memorandum was therefore prepared to this end (Bomber Command O.R.S. Report No. S.59 - 'The Advantages to be Gained by the Use of Countermeasures against Enemy R.D.F.')(1). The contribution of various causes of loss to the total wastage of bomber aircraft was first estimated, the main basis for judgment being the reports by aircrews of bombers seen to be shot down. The tentative allocation of losses reached was as follows.

	Percentage of Missing	Percentage of Total Wastage (Aircraft missing and written off)
Flak at Target	30% (2/3 while held in searchlights)	20%
Flak en route	15% (½ while held in searchlights)	10%
Fighter at Target	5% (½ while held in searchlights)	3%
Fighter en route	40% (¼ while held in searchlights)	26%
Not due to Enemy Action	10%	41% (including non-operational wastage)

It was considered that all losses to fighters en route and losses to flak unaided by searchlights were attributable to radar control. The control of searchlights was uncertain. The conclusion reached was that the potential saving by neutralising the enemy radar control was 60 per cent of the total wastage if searchlights were radar controlled and 30 per cent if they were not. A reduction of 50 per cent was regarded as a possible achievement. It was stressed that if the total bombing effort were controlled by aircraft wastage such a saving would result in a doubling of the effort, and that in addition

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the effectiveness of attack would be increased by the resulting higher level of experience in the crews and the reduction in distraction by target defences. The recommendation made was that the highest priority should be given to the development of radio countermeasures, those for use over the target being regarded as of first importance and those for use against ground control of fighters second. A copy of this report was forwarded to Air Ministry by the Commander-in-Chief with a request for the provision of suitable radio-countermeasures with the utmost importance and urgency.

The progress of technical development was reviewed about this time by T.R.E. (Report No. 5/R/69/MR 'Second Interim Report on R.C.M. Aids for Bomber Protection'), and the Command's request for urgent action generated in correspondence between Air Ministry and Command concerning practical possibilities which culminated in a conference held at Bomber Command on 6 October 1942. This conference of the Signals branch and C.R.S. of the Command with representatives from Air Ministry, under the chairmanship of the Senior Air Staff Officer, agreed that such countermeasures as were ready for application should be applied as soon as possible.

Organisation of the Enemy Defences at the Beginning of the Countermeasure Campaign

In the late autumn of 1942 when radio countermeasures became operational, the enemy had four main types of radar equipment to assist his defence. These were:-

Freya. On a frequency of 120-130 mc/s, a broad-beamed scanning system used primarily as an early warning set, but also as a putter-on for narrow-beamed ground equipments.

Wurzburg. On a frequency of 550-570 mc/s, a narrow-beamed system used for the control of anti-aircraft fire (G.L.) and it was thought probable, of searchlights (Searchlight Control (S.L.C.)).

Giant Würzburg. On a frequency of 550-570 mc/s, similar to the Wurzburg but more narrowly beamed, used for Ground Controlled Interception (G.C.I.). For this application, two of the sets were sited together, one plotting the course of the bomber and the other of a night fighter. Instructions to the fighter to guide the pilot towards an attacking position were passed by radio telephony, on a frequency within the band 3-6 mc/s.

Lichtenstein. On a frequency of 490 mc/s, an airborne aid for night fighters (A.I.). The Giant Wurzburg G.C.I. system could guide the fighter into visual range of the bomber under favourable conditions, but the Lichtenstein was often a necessary and always a useful adjunct to it.

The Freyas were deployed around the enemy-occupied coast to give continuous cover on single aircraft at 10,000 feet out to a range of 70-80 miles. Sets were also placed inland on the G.C.I. sites to help in putting the narrow beams of the Giant Wurzburgs on to targets. The Wurzburgs for gunfire and searchlight control were deployed in strength in the many gun-defended areas, while the G.C.I. sites were arranged in a belt round the northern and western approaches to Germany. Each pair of Giant Wurzburgs was used to control interception of bombers passing over a fixed area or 'box' of territory surrounding the site and contiguous with the 'boxes' of the next pairs of sites in the chain.

The sequence of events in the German system was that the Freyas secured early warning of the approach of a bomber force and alerted the defences. Fighters became airborne, if they were not already carrying out exercises, in the G.C.I. boxes and guns were manned in the gun-defended areas on the probable bomber route. In the G.C.I. belt the bomber was likely to be tracked first by a Freya, then by a Giant Wurzburg and then by the Lichtenstein carried by the fighter. There were thus three radar stages in the G.C.I. process open to countermeasures and, in addition, the radio communication between ground control and fighter, vital to the success of an interception, so could be attacked. In gun defended areas the Wurzburg was the radar control both for prediction of blind fire or for the laying on of searchlights to allow data for gunfire to be obtained visually.

Brief History of Radio Countermeasures Campaign

The first attempt to counter enemy radar was applied unofficially and in an unorganised fashion by aircrews who gained the impression in 1940-41 that switching on their radar identification device (I.F.F.) embarrassed the enemy searchlight control. This idea was after investigation exploited in the first countermeasure deliberately aimed at the Wurzburgs, Shiver, in October 1942.

At the beginning of December 1942 countermeasure Mandrel was introduced to jam the Freyas. This was followed, partly no doubt as a consequence, by the enemy's introduction of other early warning sets, the Hoarding and the Chimney during 1943.

In July 1943 countermeasure Window was introduced as a counter to the Wurzburg and the Lichtenstein. This countermeasure was not an electrical device but consisted in the production of large numbers of spurious responses to the enemy radar by means of quantities of metal foil released from the bombers. Almost immediately afterwards, the enemy largely abandoned G.C.I. and took to directing fighters en masse by directions transmitted from the ground to areas where they might hope to contact the stream of bombers and find targets for themselves with their airborne radar. Neither type of Wurzburg, was, however, supplemented by other apparatus but both were used to plot the course of the bomber stream and were modified in various ways in attempts to overcome the effects of Window sufficiently for use in gunfire control.

In February 1944 an electrical jammer for the Wurzburg was introduced as Carpet II. The Lichtenstein was also attacked by means of electrical jamming applied from a ground station, Ground Grocer and an airborne jammer Grocer was also prepared. However, early in 1944, the enemy superseded the Lichtenstein by another A.I. known as S.N.2. When this was discovered in July, specially prepared Window was employed as a counter. Later, an electrical jammer, Piperack, was directed against S.N.2 by specialist aircraft of No. 100 Group.

In support of Operation Overlord, an extensive scheme of radio-countermeasures was employed. This included the jamming of the Freyas by an improved technique in using Mandrel and the production of simulated forces by the use of Window. After the invasion, the new Mandrel technique - the Mandrel screen - and Window-aided feints were used in support of bombing operations.

The enemy countermeasures during 1944 were almost wholly designed to make use of British transmissions as an aid to or replacement for his radar. Thus, an early warning apparatus, the Heidelberg, was introduced which used transmissions from the British C.H. system, measuring the path difference

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between pulses received direct and received after reflection from aircraft. An elaborate aircraft reporting system was set up in which ground stations searched for signals known to be characteristic transmissions of British bombers and were able by this means to obtain early warning of the approach of a bomber force and to plot its course continuously. In addition, night fighters were equipped with apparatus which enabled them to home on transmissions from bombers. The countermeasure to these methods was to restrict bomber transmissions, and became known as 'Signals Silence'.

For convenience a list is given below of the dates on which the various countermeasures and other defensive devices employed were introduced.

Dates of Introduction of Radio Aids

Radio Aids	Date of Introduction	Purpose
Switching on I.F.F.	late 1940	Interference with enemy searchlight control.
J Switch of I.F.F.	8/9. 7.42	Wurzburg jamming.
Monkey (later Shiver)	13/14.10.42	Wurzburg jamming.
Boozer	13/14.11.42	Tail-warning.
Tinsel	2/3.12.42	Jamming enemy ground to fighter R/T on 3-6 mc/s.
Mandrel	6/7.12.42	Jamming Freya.
Ground Cigar	21.22. 5.43	Ground based jamming of enemy V.H.F. fighter R/T on 38-42 mc/s.
Monica I (Aural Monica)	22. 6.43	Tail-warning device.
Grocer	26/27. 4.43	Ground based jamming of Lichtenstein BC.
Window	24/25. 7.43	Confusion of Wurzburgs and Lichtenstein BC.
Airborne Cigar(A.B.C.)	7/8.10.43	Jamming of enemy V.H.F. fighter R/T on 38-42 mc/s
Corona	22/23.10.43	Confusion of enemy H.F. broadcasts to fighters.
Fishpond	October 1943	Tail-warning.
Monica III(Visual Monica)	October 1943	Tail-warning.
Dartboard	16/17.12.43	Jamming enemy MF broadcasts to fighters.
W/T Corona (Later Drumstick)	28/29. 1.44	Jamming enemy HF W/T broadcasts to fighter.
Carpet II	24/25. 3.44	Wurzburg jammer.
Fidget	16/17. 6.44	Jamming communications passed by MF navigational beacons.
Mandrel Screen	16/17. 6.44	Jamming early warning equipment by specialist aircraft.
Jostle (HF)	4/5. 7.44	Jamming enemy HF broadcasts to fighters.
A.G.L.(T)	18/19. 7.44	Blind firing + tail-warning in rear-turret.
Type M Window	23/24. 7.44	Confusion of S.N.2. (A.I.).
Jostle (V.H.F.)	11/12. 9.44	Jamming enemy fighter broadcasts on VHF.
Dina (Later Piperack)	19/20.10.44	Jamming S.N.2.

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Methods of

The countermeasures mentioned above, with the exception of Piperack and Grocer, for which little O.R.S. work other than discussion of their desirability, was carried out, are dealt with individually in the sections which follow. Methods of assessing results will emerge in each section but certain aspects of this matter, in particular the sources of information used, are common to all the countermeasures.

The object of countermeasures was primarily to reduce losses and evidence of success in this direction was always sought. Most of the countermeasures against enemy radar were expected to reduce the losses of the force as a whole and in considering these the only profitable comparison lay between losses before and after the introduction of the countermeasure. Unfortunately such comparisons were extremely difficult, in view of the many changes other than radio-countermeasures which occurred, e.g. types of bomber operating, targets attacked, tactics, conditions of weather and the state of the moon, and changes in enemy methods or equipment. Whenever possible comparisons were made in ways which eliminated some of these variables. Thus, the losses of one type of aircraft on a selected group of targets might be considered. However, results were always needed quickly in order that the need for any modifications or change in the scale of the application of the countermeasure might be perceived without delay. Therefore, it was frequently impossible to wait until sufficient sorties had been flown to provide numbers in selected samples large enough to permit statistical handling. Allowance had therefore to be made for factors other than the countermeasure by judgment and decisions taken in the light of the information available. The numbers used in the general comparison of losses were obtained from the statistics maintained by the O.R.S.

The countermeasures were expected to produce their effects by interfering with the control of specific German arms, and it was therefore possible to seek changes in the effectiveness of those arms. An index of the effectiveness of anti-aircraft fire could be provided by the extent of the damage inflicted on the bombers by flak. Fighter activity could also be gauged by the proportion of bombers reported as attacked or damaged by fighters. The statistics of damaged aircraft were obtained from the special

returns made to the O.R.S. for every damaged sortie. Information on the number of fighter attacks made was derived from the reports of aircrew as made to Intelligence immediately after each operation and forwarded to Bomber Command on Form 'Z' or from the detailed 'Combat Reports' required for each occasion when a bomber either fired at or was fired on by another aircraft. In some early analyses during 1943, the number of approaches by fighters reported by aircrews were taken as a measure of fighter activity. It was found, however, by the indications of some curious results and by the observations made by O.R.S. officers at interrogation of aircrew and at the compilation of the Forms 'Z' that the reporting of these incidents was capricious. Reliance was placed therefore only on reports on incidents where the bomber or the fighter opened fire.

Comparisons using the indices of flak or fighter activity was subject to the same interference by multiple complicating factors as has been noted for those using losses as a basis. They were, however, potentially useful as indications of the particular part of the enemy's system most affected by the countermeasure under consideration and, in addition, in the case of flak damage, usually involved larger numbers of aircraft than did loss comparisons, thereby permitting more detailed analysis.

If a countermeasure was expected to affect specially the protection of the aircraft carrying it, then it was possible to assess its effect by a comparison of the records of those aircraft with others engaged with them on the same operations. This method of assessment although freed from most of the complications besetting the comparison of records of different periods of time had its own difficulties. The method was more applicable to the consideration of the effect of the devices fitted into individual bombers to warn them of hostile activity than to the assessment of the effects of direct counters to radar, and its difficulties and developments will be considered under 'Tail-Warning Devices'.

Apart from the attempts to estimate the quantitative effects of countermeasures, it was frequently possible to learn something of the effects by observations of the enemy reaction to their application. This was largely a matter for Intelligence, but sometimes the reaction could be

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deduced from the reports of aircrews and could be detected by O.R.S. methods. Thus, the position along the bombers' route at which fighter activity was experienced might be indicative of changes in the enemy system in which case the normal reports of crews would suffice, or some specific effect like the behaviour and effectiveness of searchlights might be sought by having the crews make a special report on a pro-forma prepared to extract the expected information. Other effects could only be perceived by Intelligence methods, e.g. changes in frequency of enemy radar could be perceived by listening equipment, as could the reactions of the enemy fighter controllers. Such methods frequently gave the earliest qualitative information of the success of our countermeasures and were of great value.

I.F.F. Mark II, the J Switch and Shiver Coho

Exploration

Persistent reports from aircrew that the switching on of I.F.F. Mark II was followed by dousing or falling away of enemy searchlights caused considerable controversy during 1941. Was it cause and effect, and if so, what was the cause and what was the effect ? If there was genuine jamming of enemy radar it was desirable to make the most of the effect but if, as was argued by A.D.I.(Science), the enemy might deliberately encourage the switching on of I.F.F. for ends of his own, then the use of I.F.F. must be restricted. The O.R.S., in September 1941 after examining the available evidence and the several theories, found that no firm conclusion could be reached. A judicial summing up and a programme of action designed to produce evidence necessary to permit a definite decision to be reached were put forward (Bomber Command O.R.S. Report No. 10 'The Effect of I.F.F. on German Searchlights'). (1)

The programme went to the root of the matter in requiring a full investigation into the mechanism of the effect and suggested special experimental flights in 'flying laboratories' manned by scientists. It was discussed at a conference held at Bomber Command on 26 September 1941. The general principles were accepted and it was agreed that 24 aircraft should be provided with a simple visual indicator designed to reveal

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whether the I.F.F. was being triggered off over enemy-held territory. One flight was made with such an indicator. The results of the flight were, as expected, inconclusive, but they showed that the indicator was probably capable of giving useful information (Report No. 16 'Effects observed by Bomber Crews using I.F.F. fitted with Visual Indicator'). (1) Information about the precise effects observed by aircrews was also gathered by personal interrogation but this only confirmed the conflict of evidence.

The 'J' Switch

Before the full programme of investigating flights could be launched, the capture and examination of the Bruneval Wurzburg revealed that there was a possibility that a squittering I.F.F. could interject an interfering radiation into the I.F. stage of the Wurzburg receiver. Without further investigation, therefore, it was decided to make the use of squittering I.F.F. universal throughout the Command by incorporating a modification into the I.F.F. set to enable a permanent state of squittering to be produced by the closing of a switch. This modification was called the 'J' switch.

The O.R.S. prepared to investigate the effects produced by this device. A questionnaire dealing with illumination by searchlights was drawn up and sent out to all squadrons to be filled up for every operational sortie made with the 'J' Switch.

The replies to the questionnaire collected over a period of one month were analysed (Bomber Command O.R.S. Report No. 50 'The Effect of the use of the 'J' Switch of the I.F.F. on Enemy Defences'). (2) The whole force was equipped with the 'J' switch, and the only possible basis of comparison was the number of illuminations by searchlights suffered by aircraft using the device only after illumination and the corresponding number for aircraft who had the switch closed continuously. It was assumed as probable that, if the switch produced any effect, beneficial or evil, such an effect would be much more pronounced for aircraft using it all the time. No difference was found between the two classes. Some

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previous records of searchlight illumination were available from answers to a questionnaire used for a month in March/April 1942. Comparison of these with the results obtained after introduction of the 'J' switch, insofar as the nature of weather conditions and target, permitted it, also failed to show any change which could be attributed to the 'J' switch. The proportions of sorties missing, damaged by flak and attacked by fighters for each of the operations when the 'J' switch was used compared with corresponding proportions in previous comparable operations. For this purpose 'comparable' operations were operations reasonably similar in regard to geography, weather and state of the moon. Again, no evidence for an effect of the 'J' switch was obtained.

The replies to the searchlight illumination questionnaire did reveal that many crews had confidence in the 'J' switch and Report No. 50 (1) which presented the results of the analyses referred to above, pronounced the following judgment: 'Any device which gives crews an additional sense of protection is useful provided that it has no adverse effect on other directions. Such an aid may reduce losses and should certainly tend to increase the proportion of aircraft finding the target'. As the further development of countermeasures continually provided results impossible to assess quantitatively, this pronouncement came to apply to many equipments later.

Shiver (Monkey)

While the operational trial with the 'J' switch was in progress, T.R.E. were devising a further modification to the I.F.F. set. The effect of this was to improve the power radiated in the frequency band which examination of the Bruneval Wurzburg had suggested as most worthy of attention. Report No. 50 dealing with the inconclusive results obtained with the 'J' switch, recommended operational trials with this new modification.

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In discussion with the Signals Staff a plan was made for assistance to be given in assessing the effect of the new device by confining the installation to one group for an initial trial period. This was agreed, and No. 1 Group was fitted with the device which was given the code name of Monkey, later changed to Shiver 4.

There was a natural aversion to delay the full introduction of any device which was designed to reduce losses, and when the fitting of No. 1 Group was complete, installations in other groups followed. Thus, the period available for a direct comparison of 'fitted' and 'non-fitted' aircraft was very short. Had records been kept of the dates on which the various aircraft were equipped more data would have been available for analysis. As it was there were only two operations in October 1942 in which No. 1 Group alone had the device. An O.R.S. investigation was made by comparing the casualties of No. 1 Group with those of the other groups for these two operations. This comparison revealed no advantage in the use of Monkey. The intercepted night fighter R/T for the first night of operation Monkey did, however, contain four references to interference. These were not regarded by the O.R.S. as anything but a hopeful indication but they helped to precipitate the fitting of the whole force. Thereafter, no attempt at assessment of the value of Monkey, or Shiver as it then became known, by comparison of users and non-users was possible.

Use of Shiver continued until the introduction of I.F.F. Mark III became imminent. An assessment then became necessary since the retention of Shiver with Mark II involved a duplicate I.F.F. installation. Such facts as were available were marshalled and presented to the Signals staff. The bases of assessment were comparison of the incidence of flak damage before and after the introduction of Shiver, indications from Boozer (1) equipped aircraft that they were held by Wurzburgs with Shiver working and evidence from intercepted enemy night fighter control traffic. No evidence that Shiver had a protective effect could be shown and as

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(1) A device discussed on page 473.

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arguments against retention of the device it was pointed out that interference with our own Gee-H stations and with Gee had occurred and that, moreover, if any effect had been produced the enemy had had ample time to introduce effective counters and might then attempt to home on the radiation. It was suggested that experimental flights with Boozer or with special listening equipment would determine whether Shiver was completely without effect on the Wurzburgs. The arguments against continuation with Shiver were, however, accepted and these trials were not carried out.

Preparations for Mandrel use

In early considerations of the effect of countermeasures against enemy radar, the O.R.S. always placed the greatest stress on the need for jamming the Wurzburg equipment, the gear directly controlling offensive weapons. Thus, O.R.S. Report No. 4,(1) referring to countermeasures against the enemy's coastal radar chain on 250 cm, stated 'These are not considered vital to Bomber Command's night operations unless these stations are being used for "Little Screw"', the name by which the enemy G.C.I. system was then known. The problems of designing jamming transmitters proved, however, to be easier to solve for the early warning chain of Freyas than for the Wurzburgs and a device known as Mandrel came into production in 1942. This equipment was a noise jammer designed for airborne use to cover the frequency band of the Freyas. A fixed form of the equipment was also designed for operation from stations on the south coast. The design of the equipment was, of course, the responsibility of T.R.E., who also estimated the proportion of bombers which should be fitted with the device. The O.R.S. was still stressing the greater need for Wurzburg jamming, but in discussions during 1942, welcomed Mandrel as a first instalment of radio-countermeasures, particularly insofar as it might prevent the use of Freyas as putters-on for Wurzburgs. Little detailed work was, however, carried out before Mandrel became operational.

First Use of Mandrel

Mandrel was first used on 6/7 December 1942, and its effects were sought by the O.R.S. with considerable care. The largest expected effect was the reduction of the enemy's early warning of the approach of the bombers. An attempt was made, therefore, to assess the effect by comparing

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the time intervals between the bomber aircraft crossing the enemy coast and the initiation of enemy fighter activity, before and after the introduction of Mandrel. The indices of fighter activity used were the first operational night fighter R/T hears and the first reported time of sighting an enemy fighter by a bomber crew. The records of coastal monitoring stations were also examined in order to discover abnormal behaviour of Freyas which could have results from Mandrel. At the same time the losses of aircraft carrying Mandrel were compared with those of other aircraft in order that any attempt by the enemy to select the carriers for special attention should be appreciated without delay.

The results obtained were discussed with the Signals branch as they became apparent. They included some encouraging features, particularly in regard to enemy frequency changes, but during February anxiety developed about the losses of Mandrel-carrying aircraft. As was later true for many similar investigations, elucidation of the true facts was hampered by unsatisfactory and often conflicting information from the squadrons as to which aircraft used the equipment.

The comparative position in regard to losses together with the evidence for the effectiveness of Mandrel was stated in two notes passed to the Signals branch at the beginning of March 1943. The first of these, considering the results to the end of February, expressed considerable anxiety about the hazards of Mandrel aircraft in view of their comparatively high losses during the second half of February, and of a reported manifestation of hostile activity against the fighter aircraft which were forming a Mandrel screen. The second report included data for the first week of March which indicated a reassuring trend in Mandrel losses. This report, making the point that the evidence available only showed an effect of Mandrel on coastal Freyas, suggested that Mandrel should be switched off when the enemy coast was passed or alternatively that the jamming should be carried out by specialist aircraft better able to defend themselves than the operational bomber.

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The Signals branch which had been allaying the fears of the squadron about homing with well-chosen data on Mandrel losses were rightly anxious that no step should be taken which would increase such fears. Moreover, the Mandrel sets were being modified to produce a ±3 mc/s wobble in the carrier frequency in order to hinder direction finding on the source of jamming. It was therefore decided to await further results and the investigation continued regarding the delaying action of Mandrel on the enemy's reaction and also losses.

Freya-Halbe, an Enemy Homer

At the end of March the losses of Mandrel aircraft were shown to be similar to those of other aircraft, but there was no evidence, from the time of the first night fighters R/T traffic picked up or, from the time of the first interception of a bomber that any delaying action was being produced. During May 1943 information became available that the enemy was developing a homer for use against Mandrel known as Freya-Halbe. The O.R.S. maintenance of statistics of losses was useful in showing that no effect of the use of such a device could be detected. Nevertheless, the threat could not be ignored and discussions on protective measures were carried on with the Signals branch and T.R.E., and with Fighter Command who carried out homing trials against Mandrel-equipped aircraft. The O.R.S. function was largely to interpret the flight trial results in relation to Bomber Command operational conditions. The final decision was that Mandrel transmissions should be interrupted so that two minutes radiation was followed by two minutes silence.

The evidence relating to the effectiveness of Mandrel, and to its effect on losses of aircraft carrying it, was summarised in July 1943. It had to be concluded that the O.R.S. methods of analysis failed to reveal an effect owing to the operation of many conflicting factors and that the only evidence of value was that provided by secret sources. It was pointed out, however, that with the imminent introduction of Wurzburg jamming by Window, the jamming of inland Freyas would become of prime importance and that steps should be taken to increase the effective application of Mandrel and to survey the frequency distribution of the inland Freyas.

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Close watch was kept on Mandrel losses, but apart from a brief period of excessive losses by No. 4 Group Mandrel aircraft in June 1943, no cause for anxiety appeared until the end of the year when, in No. 4 Group, losses of fitted aircraft again began to rise relative to the others. Although for No. 4 Group there were heavy odds against the difference between losses of fitted and unfitted aircraft occurring by random chance, there was no appreciable difference for other groups. Even in No. 4 Group, returning Mandrel aircraft did not report attacks by fighters more frequently than did others. An investigation was made therefore into the possibility that in No. 4 Group, the aircraft fitted with Mandrel were in some other way a special class, e.g. they were flown by inexperienced crews. No idiosyncrasy was, however, found and no adequate explanation could be offered. The results were circulated within the Command Headquarters with the suggestion that as no physical explanation could be found for the effect, Mandrel operation should be continued and if possible increased with a more extended frequency coverage. ('Losses of Mandrel-carrying aircraft, November 1943 - January 1944')(1) Further experience showed that this advice was sound, for losses subsequently fell alike on the fitted and the unfitted aircraft, and Mandrel proved to be of great value in the re-entry to the Continent, an operation which was now beginning to pre-occupy both the planners and producers of equipment.

The Mandrel Screen - Preliminary Planning

It became obvious early in 1944 that any substantial increase in Mandrel coverage of the bomber force was unlikely to be possible until requirements concerned with the invasion of Europe were satisfied. The O.R.S. studies of enemy fighter tactics had long since led to the view that any delays in the enemy's perception of the direction of approach of a raiding force would reduce losses. Therefore, when the formation of a specialist Mandrel squadron with full frequency cover over the enemy's early warning chain was mooted as a possibility for use in the landings in Europe, it was pointed out that such a squadron would be of great value to the bomber force. When the creation of this squadron had been agreed

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and when assault preparations had also stimulated the development of a type of Window covering the Freya band, some discussion on the future of Mandrel took place with the Signals branch. It was agreed that the O.R.S. would prepare an appreciation of the situation. The result was Report No. S.148 - 'The Possible Uses of Mandrel and Freya-Window against the Enemy Early Warning Equipment'.(1) This paper made no attempt to draw on past experience, but was a theoretical treatment of the way in which Mandrel in the quantities available and Freya Window could be used to achieve screening of the approach of a bombing force, protection against G.C.I. by inland Freyas and the simulation of a bomber force by small numbers of aircraft. It was argued that:-

(a) the concentration of aircraft in the bomber stream was large enough without further aid to prevent Freya G.C.I. except on the edges of the stream, but the Mandrel should be retained in the main force until there was evidence of enemy exploitation of the radiation for plotting or homing in order to give protection to the edges of the stream.

(b) the approach of a force could best be screened by disposing the specialist Mandrel aircraft at suitable positions some 50-70 miles from the enemy coast, the positions to be chosen specially to cover the route concerned.

(c) good diversions could be produced by about 24 aircraft releasing Window.

(d) Mandrel screen and diversions which could most profitably be used together, should be employed with maximum possible variation and should be used to rouse the enemy defences on non-operational nights.

It was also suggested that the value of screening was great enough to justify forming a screen with Mandrel cover only against the long range Hoardings and Chimneys as an interim measure while full cover for the Freyas was prepared.

Mandrel Screen - Tactical Planning

On receipt of this paper the Commander-in-Chief Bomber Command ordered that detailed plans should be prepared for the operation of the Mandrel screen and Window-aided spoof forces. A map of the known

(1) A.H.B./II/69/175(B).

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positions of the enemy early warning radar stations was prepared, and for a large number of positions of a set of eleven jamming centres, the areas screened from enemy observation was calculated. The first process was to select a distance from the coast for the jamming aircraft to fly. This was a matter of judgment since the demands were conflicting. The closer the jammers were to the coast the more the screened area would decrease since the spacing between centres is governed by the beam width of the enemy radar. On the other hand it was felt that it was desirable for two forces to emerge from the screen headed in a way which would imply threats to well separated targets. It was evident that this could only be achieved if the screen were well away from the enemy coast. The maximum distance possible with the operation of monitoring necessary with Mandrel III was 80 miles, and this distance was selected.

Even at this distance it was decided that complete cover against the narrow beamed Hoardings was not possible if adequate breadth of cover were to be provided. Since the screen could not delay early warning sufficiently to prevent full fighter reaction against a single bomber stream flying anything but a very shallow penetration, it was considered that the aim of the screen should be maximum confusion rather than full black-out. Therefore, complete cover against the Hoardings could be sacrificed to produce increase in breadth of the area of screening.

These judgments having been reached, the whole matter was discussed at No. 100 Group and quantitative estimates of the cover provided for certain positions of the screen were made. The method used was to pin on the map of the German coastal radar paper triangles cut with their apex having the value of the beam width of the radar concerned, to place the jamming centres at about 80 miles off the coast, and to determine the positions which promised the best screened area. The expected limits of the screened area were calculated on the basis that jamming would be adequate at a signal to noise ratio of 1 to 1, and the best heights for the screen aircraft to fly at the various positions were calculated from the known characteristics of the jammers and of the enemy equipments. When the areas

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of screening were determined, the routes and timing of raids and feints through the screened area were considered in the light of knowledge of the enemy's probable reactions derived from study of fighter movements on recent operations.

The problem was complicated by the destruction of early warning sets on the invasion preparation and finally a considerable readjustment was imposed by the capture of Cherbourg. Thus, by the time the plans were fully prepared and issued within Bomber Command (Bomber Command O.R.S. Report No. B.216 'Proposals for the Tactical Use of the Mandrel Screen'), (1) the screen had already commenced operations, and the changing military situation was already affecting the enemy's reactions. The general principles developed in the report were, however, independent of particular circumstances and were useful in planning screen and diversion operations. The preparation of the report is dealt with at some length here as an example of how in an apparently largely quantitative matter, many conflicting claims had to be resolved by judgments.

Mandrel Screen - Assessment of Results

Results produced by the operation of the Mandrel Screen and of Window-aided diversions were sought by the O.R.S. both at No. 100 Group and at Bomber Command. The changing military situation and the introduction of other countermeasures spoiled any evaluation by comparison of losses or of the extent of fighter reaction for periods before and after the use of the screen. It was necessary to give individual attention to each operation and to compare the time and nature of the enemy's reaction as revealed by his W/T and R/T plots on the bomber position and orders to fighters. It was clear that, although there were frequently enemy plots of bomber positions behind the Mandrel screen, in general the expected area of confused and isolated plots was being produced. It was not possible to discover any system in the appearance of early plots.

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(1) A.H.B./IIN/a1/4a App. O.R.S.

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The Window-aided diversions also seemed to have success but also to fail occasionally without any obvious systematic cause. It did appear, however, that the Window diversions had their best successes when directed towards areas which had recently been heavily attacked and about which the enemy had been made sensitive while the real bomber force attacked a target in another area. The results were thus more or less as expected, and in writing an appreciation of the first five weeks of operations (Bomber Command O.R.S. Report No. S.172 'First Operations of the Mandrel Screen and Special Window Forces')(1) attention could only again be drawn to the deficiencies in the screen and diversions which had been referred to in the two papers on the methods of employment of the Screen (Report Nos. S.148 and B.216) and to one new development, revealed by investigating flights, an enemy early warning system on a frequency of about 36 mc/s. It was recommended that:-

(a) Carpet be fitted in the jamming aircraft to prevent plotting by coastal Wurzburgs.

(b) Measures to ensure the maximum possible restriction on radiation from the approaching bomber force should be accelerated together with the inclusion on diversionary forces of any radiator which had to operate in the bomber force.

(c) Steps should be taken to provide for jamming of the suspected enemy 36 mc/s early warning set.

(d) Trials of a Window diversionary force should be made against captured enemy equipment.

(e) The investigating flights of No. 192 Squadron should be supplemented by use of Bagful(2) in the bomber force.

With the exception of (e) all these recommendations were carried into effect, although (d) had to wait until March 1945 for its fulfilment. The recommendations put on paper in orderly fashion were already common thought at No. 100 Group, and in the Signals branch at Bomber Command, but as in other cases their issue in official form with a reasoned backing no doubt helped to produce action.

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(1) A.H.B./II/69/284.

(2) A device for recording enemy frequencies.

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Investigation into the effectiveness of screen and diversions continued without revealing any new enemy means of defeating their object. It became suspected towards the end of 1944 that the enemy's broadcast plots and directions did not begin when he obtained his first plots but were timed so as to sustain for British benefit an illusion that the screen was delaying his action somewhat longer than was in fact the case. There could be little check on this. An attempt was made by comparing the times of first plots with the times of switching off enemy broadcast transmitters, with inconclusive results. Examination of the data concerning the occasions when enemy fighter movements appeared to precede plots of the bombers' position suggested that no more than the intelligent anticipation of the direction of attack had been made, based either possibly on the position of the Mandrel aircraft or on intruder activities.

Unfortunately for the purposes of investigation the few occasions when Mandrel was not used were marked by some other peculiarity and gave no real clue to the enemy's state.

The efficiency of the Mandrel screen came into question after the military advance to the Rhine, and a final appraisal of its value was made in a minute to the Air Staff on 3 April 1945. This summarised the investigation of operations for the months of February and March. In effect the result was that obtained throughout the period of the operation of screen and spoofs, namely that sometimes they worked and sometimes they did not as was to be expected from their known deficiencies. It was pointed out that the enemy had begun to associate the appearance of the screen with an operational threat and that low level approaches without a screen would probably achieve a surprise. Heavy bombing became unnecessary before further developments could be pursued.

The end of Main Force Mandrel

The withdrawal of Mandrel from the bombing force is worthy of comment. In early May 1944 suspicion grew that the enemy was operating an A.I. equipment in a frequency of 160-170 mc/s. Methods of countering this were discussed with the Signals branch, and it was concluded that Window could be

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supplemented by modification of Mandrel sets to cover the required task. The conclusion reached in Report No. S.148 that the concentration of the bomber force was high enough to defeat Freya G.C.I. was accepted as permitting withdrawal of Mandrel from its original duty of jamming the most populous Freya band. T.R.E. reacted against the proposal pointing out that the jamming of the A.I. by modified Mandrels would be inefficient and that modification of I.F.F. Mark II would be a better proposition. The question was discussed at length by the Signals branch, T.R.E. and O.R.S. O.R.S., while agreeing with the quantitative arguments of the T.R.E. view, supported the Service thesis that to be able to do something immediately was to be preferred to something better after a delay which, as experienced with other equipment had shown, might be very many months. There could be no quantitative justification for the arugment. It might have been that Mandrel jamming would have left the A.I. with enough range to give the operators as many contacts as they could deal with. Once again the basis of action was judgment, this time derived from a belief that anything which would give additional worry to the fighter crews, already harassed by communications jammed, was worth trying. The principle of converting Mandrel was accepted but no firmer news of the 160-170 mc/s A.I. came in, and when the S.N.2 (90 mc/s) became known Mandrel was finally withdrawn from the main force (28 July 1944). The use of long Window and the desire to restrict radiation from the main force made its re-introduction unnecessary and undesirable.

Window — Cafo.

Initial Considerations

The idea of releasing conducting bodies from aircraft in order to confuse radar observations had been in mind since the early days of the development of the military application of radar. It became an early interest to the O.R.S. at Bomber Command, and on 5 September 1941 in a memorandum to D.C.D. experiments on the subject were asked for without delay. In this memorandum it was pointed out that the enemy radar used for searchlights and flak was working on a wavelength of 53 cm and might therefore be countered if each aircraft carried a number of bundles of dipoles of length 26 cm cut from aluminium foil to be thrown out when near ground defences.

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After many months of discussion and following trials conducted by T.R.E., Window, the code name allotted to the operation of releasing conducting bodies to deceive radars, became an operational possibility in April 1942. A draft instruction for the use of the countermeasure was prepared by the Air Staff and circulated to the Signals branch and to O.R.S. for comment. The Window material then available was in the form of metal foil propaganda leaflets of size $8\frac{1}{2}$ inches x $5\frac{1}{2}$ inches and a bundle sufficiently large to produce an aircraft echo on the enemy's Wurzburg had been estimated by T.R.E. at $4\frac{1}{2}$ pounds. Thus the number of bundles which an aircraft could carry was severely restricted, and moreover, the amount of material available was small. The advice given, therefore, was to ensure that best possible use was made of the amount carried by defining areas of use and rates of release. It was suggested that the main effort should be made at the target, the only place where the concentration of aircraft could be expected to be sufficiently great to give results with small quantities of Window. The rates of release required to produce the concentration of Window of 10 echoes per square mile recommended by T.R.E. were worked out, and it was suggested that the first 20 aircraft over the target release one bundle every half-minute over the target, and the remainder one bundle per minute for periods of eight minutes in each case. It was also suggested that aircraft threatened by searchlights on route should release four bundles at half-minute intervals and orbit.

The operational use of Window was banned before such instructions could be put into practice due to fears of retaliation by the enemy, but the approach which had been made towards operational use stimulated great interest in the development of the best methods of use.

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The Development Stage

Trials were carried out by the Air Defence Research and Development Establishment with T.R.E., with the primary object of exploring the effect of Window on the defences of the United Kingdom, but with the secondary object of deciding the best methods of employment by the Bomber force. These trials were watched by the O.R.S. to ensure that the secondary object received full attention.

On 4 November 1942, the Chief of Air Staff called a meeting of the interested parties to discuss the next step. The prospective value of Window to Bomber Command had therefore to be assessed, and the O.R.S. collected and weighed the available evidence. Calculations based on the results of the recent trials suggested that if the enemy G.C.I. system was to be neutralised by means of Window, about 90 pounds of foil per minute would have to be discharged by every aircraft. It was therefore considered impracticable to use Window for protection along the route. The usefulness of Window was considered therefore to depend on the losses due to radar-aided defences of the target area. Investigation of this and related problems had been and continued to be an unceasing groping. The lines of enquiry available were the reports of aircrews of their observations during an operation, the damage to returned aircraft, intercepted enemy R/T fighter control and odd scraps of information from secret sources. Each source of information required careful interpretation in order to correct the presumed bias in the sample covered. An account of the results obtained from the various methods of approach may be seen in Report No. S.91 'Night Bomber Losses on German Targets, 1942'.(1) In November 1942 the evidence indicated thatlosses were being incurred as follows.

Not due to enemy action	0.5% of sorties
Fighters en route	2.25%
Fighters over the target	0.25%
Flak en route	0.6%
Flak over the target with aid of searchlights.	1.0%
Flak over the target without aid of searchlights.	0.4%
TOTAL	5.0%

It was therefore considered that in view of the prohibitive amount of Window required for effectiveness along the route, the maximum saving to be expected from Window was the loss due to radar-controlled flak at the target

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(1) A.H.B./II/39/1/1.

area, i.e. about half per cent of sorties if the searchlights were not radar-controlled and about one and a half per cent if they were. Because of the comparatively small benefit expected, of concern lest Window interfere with H2S and of the much greater benefits anticipated from Monica, O.R.S. opinion at this stage was luke-warm about Window. In consequence, the Command representatives at the Chief of Air Staff's meeting did not press for immediate use of Window in face of Fighter Command's opposition dictated by the serious threat to our own defences which would be produced by presentation to the enemy of knowledge of the countermeasure. It was agreed that consideration of the use of Window should be deferred for six months, this period to be spent in improving counters to enemy use of it and in devising the best methods of use and ascertaining the quantities required for operation of Bomber Command.

Preparations for Introduction

In pursuance of this direction, estimates of the rates of release of Window required to defeat the enemy's control of flak or of fighters by Wurzburgs were made by Fighter Command and by A.D.I. (Science). The Fighter Command estimate was based on a rather stringent requirement for blacking out completely the presentations of the Giant Wurzburg and the Small Wurzburg to ranges of 15 miles and five miles respectively. The rate of release called for was five aircraft echoes of Window per minute from every bomber, although it was suggested that lower rates would produce a useful degree of comparison. A.D.I. (Science) considered that the Fighter Command requirements were unnecessarily severe, but that at the same time they failed to take into account the uneven distribution of Window which would exist within the bomber stream. He concluded that about 5/8ths of the Fighter Command quantity would be sufficient to make the enemy's Wurzburg unusable and that for initial use sufficient confusion could be produced by about one-fifth of that amount. Further, it was considered that, if the Window were released by a special force flying above about the bomber stream, the total amount of Window required would be reduced by a factor of two to three. There were many incompletely known factors involved and it and it was left to O.R.S. to examine the two estimates judicially and to

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arrive at a release rate which would give good hope of success and which could would be maintained by the bomber crews. Judgement was pronounced in Report No. S.79 'Operation Window'.(1) The first conclusion was that release by a special force must be rejected owing to a lack of confidence that such a force could keep its position in relation to the bombers sufficiently well. It was considered that the assumptions made by A.D.I. (Science) were in general justified but that, since they were assumptions with only a skeleton backing of fact, a safety margin must be allowed. Moreover, there was some hope that the release of two bundles per minute would affect seriously the enemy A.I. (Fighter Command Report FC/S31389/Sig.J. of 8 January 1943).(2) The conclusion reached was that the preferred rate was two bundles per minute from every aircraft, but that sufficient confusion would be produced on the first few operations by a rate of one bundle per minute along the route with two bundles per minute within 20 miles of the target. The increase rate over the target area was suggested because a comparatively small increase in weight carried could ensure success in an area sure to contain a considerable concentration of Wurzburgs.

The operation considered for the estimates was an attack on Cologne and it was suggested that in view of the wide G.C.I. belt to be crossed, Window release should commence and finish 20 miles from the enemy coast. The conditions assumed, 300 aircraft spread on a front of 20 miles and passing a front at a rate of ten per minute, should, with the height spread of about 7,000 feet, produce a concentration in space of about 0.1 bundles per cubic mile and a release rate of Window of one packet per minute should produce a density of about one Window echo per cubic mile, i.e. about a quarter of the density estimated as necessary to black out completely the Giant Wurzburg presentation beyond a range of 15 miles, even assuming that the distribution of Window throughout the bomber stream was uniform. Considerable reliance was thus placed on the A.D.I. (Science) view that the enemy would be unable to distinguish aircraft echoes from Window echoes. Report No. S.79 recommended that further experimental work should be carried

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(1) A.H.B./ID/12/149.
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out in order to determine the form of Window bundle which could with the greatest economy in weight produce the appearance of an aircraft echo both on the Wurzburg and on the Lichtenstein A.I.

The O.R.S. estimate was accepted by the Command and was referred to Air Ministry as the basis for estimating production.

The Final Fight for Introduction

The Chief of Air Staff called his promised further meeting on 2 April 1943, in order to consider the operational introduction of Window. New estimates of the quantities required made as a result of improvement in the form of the countermeasure since the previous meeting in November, had produced a considerable change in attitude towards it since it was clearly now practicable to apply it all along the bombers' route. Accordingly, the O.R.S. view put to the Commander-in-Chief before the Chief of Air Staff's meeting was that 'there was now a good possibility of saving one-third of our losses on German targets by using this countermeasure', and that 'the Command has nothing to lose and possibly much to gain by using it'.

The Chief of Air Staff's meeting at which Bomber Command was represented by the Commander-in-Chief and the Officer-in-Charge O.R.S. agreed to recommend to the Chiefs of Staff that Window should be employed as from 1 May 1943, and to expand the production of the material. This initiated a period of further argument on the merits of Window and of drawbacks which might be expected. The proposals for expansion of production promptly generated a plea that the country's aluminium production would be unable to meet the drain. It was, however, pointed out that a bomber contained about 10 tons of aluminium so that the saving of one or two bombers a night by Window would leave the country's aluminium supply unimpaired.

Other points in connection with the defences of the U.K. and of North Africa arose to postpone the use of Window. The O.R.S. could do little to settle these, but gave continuous support for the earliest possible use by Bomber Command in such discussions as arose.

Preparations for the introduction went on. Methods of launching from bomber aircraft and flights were made to test methods of ejection from existing chutes. The operational area in which discharge should take place

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had to be prescribed. The map of the known positions of the G.C.I. stations was examined and an area embracing them was delineated. It was suggested that the necessary economy in Window would be aided by confining discharge to such an area. This suggestion was accepted and the map concerned was attached to the operational instruction on the use of Window.

As the use of Window became a more probable event, it became evident that some difficulty would be experienced in meeting the Command's needs. The supply position was considered in relation to probable consumption and the conclusion was reached that the production planned in mid-July 1943 would be insufficient to meet operational needs. It was suggested to the Air Staff that initially the release rate should be restricted to one bundle per minute throughout an operation, including the target area, and that shortest possible routes should be taken through the G.C.I. area. This release rate was agreed, with the proviso that future action should be based on the results obtained in initial operations.

First Operational Use

Window came into use for an attack on Hamburg of 24/25 July 1943. For this operation several O.R.S. officers were at squadrons to obtain from the crews first-hand accounts of visible effects of the countermeasure on the enemy defences and of the difficulties experienced in discharging the bundles. They were able from the crews' accounts of the feeble behaviour of searchlights and of the deterioration of flak defences to appreciate that Window had had a telling effect. They also learnt that better methods of opening the bundles, packing them and of ejection from the aircraft, were desirable.

The evidence concerning the first two Window operations was surveyed with great care and was presented in O.R.S. Reports No. S.95 'Immediate Report on the use of Window on Hamburg, 24/25 July 1943,'(1) and No. S.96 'Interim Report on the use of Window on Essen, 25/26 July.'(2) The success of the countermeasure was assessed taking as yardsticks bomber losses and the indices of enemy defensive activity provided by the proportion of bombers damaged by flak, attacked by fighters and damaged by fighters. The values of these indices for the Window operations were compared with the

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corresponding values, for operations against the same or similar targets during the previous year. In addition, the intercepted enemy night fighter R/T was combed for evidence of the type and extent of Window interference. This source made it abundantly clear that the enemy was completely confused and was not readily able to distinguish Window echoes from true aircraft echoes, a supposition which had been relied on in estimating the quantities of Window required.

In addition, an attempt was made to determine the position relative to the remainder of the force of the bombers which were lost or of those which, from their reports of damage or attack, had received attention from the enemy defences. It was hoped that in this way to discover how complete was Window production within the main bomber stream, how adjustments of flying height might make it more complete, and what success the enemy was having in exploiting parts of the force less well protected by Window.

The investigation of individual raids was continued for some time and appreciation of the first ten Window operations was prepared (Report No. S.98 'The Effect of Window on Bomber Operations').(1) The saving of bombers brought about by the use of Window, assessed by comparison with previous experience on similar targets, was estimated as a reduction of rather more than one-third, a fraction in good agreement with the forecast made in the previous November. The losses sustained by aircraft bombing in the several individual waves of each operation was considered, and it was shown that the results expected from the changes in Window cover produced by changes in flying height were being realised. Thus, a low flying wave following a high flying wave tended to have low losses whereas a high flying wave following a low flying wave tended to have high losses. Suggestions were made for the ordering of waves in such a way that the greatest benefit from the use of Window would be obtained. These were accepted by the Air Staff.

In addition, an attempt was made to assess the adequacy of the rate of Window release. It was not possible to say that the enemy was having success only against stragglers or high flying aircraft. It was, of course, impossible to discover for certain which, if any, of the aircraft lost

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(1) A.H.B./ID/12/113.

were straggling and only a large effort in analysing navigators' logs could reveal which of the returning aircraft had been on the edges of the stream. (This analysis was considered, but the labour to perform it was not available). The comparison of the losses of separate waves suggested that not very large diminutions of Window concentration were sufficient to give the defences an extra opportunity and that therefore the amount of Window dropped could not, with safety, be diminished. The intercepted enemy R/T traffic suggested strongly that some G.C.I. equipment was still having successes, but it was found impracticable to determine its position with relation to the bombers' route sufficiently well to say whether the victims were stragglers or not. Comparison of the type of orders given in G.C.I. with those obtaining before the use of Window also failed to give a guide as to the extent of Window interference. There was, however, a new form of traffic in addition to G.C.I. apparently involving an alternative, and much looser form of fighter control, and this was taken as some evidence that the G.C.I. system was considerably embarrassed. The absence from the R/T traffic of references to interference on A.I. was difficult to interpret. It was possible that the Window was having little effect on this apparatus, but the possibility that good enemy security had prevented references to A.I. restrained conclusions on this point.

There was thus no good evidence from operations concerning the desirable concentration of Window. It was reasonably clear that no great reduction could be made, and it was recommended that release rates should remain unchanged until further experience had been gained with an improved plan of waves of attack.

Expansion of Production

The success of Window, following a period when the need for secrecy had severely restricted the spread of production, called for immediate planning for expansion of production. Since large quantities of material had to be imported, orders had to be placed to cover a long period ahead and O.R.S. embarked in July 1943 on a task which was to recur at frequent intervals until the end of the European war forecasting the probable future Window consumption of Bomber Command. This involved guesses at the rates of dropping which would be required, the distances likely to be flown through

areas where Window release was required, and the probable scale of effort. For the first estimate it was suggested that a stepping-up of release rates to two bundles per minute would soon become necessary and that a further 50 per cent increase within three months must be envisaged. The need for these increases was anticipated owing to the expectation that the enemy radar operators would soon become used to working through Window, and that the enemy's new methods of loose control of fighters might make desirable a reduction in the bomber concentration. The estimated requirements of half-million bundles in August, rising by a quarter of a million bundles per month to one and a half millions in December, was put before a meeting at Air Ministry on 6 August 1943, and was accepted as a basis for ordering materials and equipment.

It was soon evident that production could not be stepped up in time to meet the consumption estimated, and the O.R.S. took on the task of stock-keepers estimating after each operation the amount of Window which had been used from the mileage flown and the number of aircraft taking part, and keeping the Air Staff informed daily of the stock position. On 18 August 1943 the Air Minister set up a panel under the chairmanship of Wing Commander Jackson now at T.R.E., to explore the many problems connected with the necessary increase in Window supply, development of new forms of Window, and launching Window from aircraft. Bomber Command was represented by the O.R.S. on this Window panel which was to continue its work until the end of the European war.

Further Developments of Window against Wurzburgs

Through meetings of the Window panel and personal contacts, close touch was maintained with the M.A.P. branches responsible for organising production and estimates of production were carefully considered together with the figures for stock and consumption in order to prepare for any measure of economy in consumption that might become necessary. In order to prepare for economy measures, study of individual operations was continued. This showed that most of the fighter opposition was met on the return journey and since it was believed that concentration on the outbound route was much better than on the homeward route, a recommendation was made that the rate of Window release should be halved to one bundle in two

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minutes on the outward route as an experiment. This trial was carried out in an operation against Munchen Gladbach on 30/31 August, and no alteration in the effectiveness of Window could be perceived. At the same time, studies of the location of combats and of enemy R/T had shown that G.C.I. was being practised in areas not included in the original Window release zone, and that considerable fighter opposition was developing over the target areas, presumably with the aid of A.I. (Report No. 80 'Some Notes on the Defensive Tactics now used by the Enemy - August 1943'.(1) It was therefore suggested to the Air Staff that the area within which Window was to be released should be enlarged, that the rate of discharge within 20 miles of the target should be increased to two bundles per minute, and that the reduced release rate on the outward journey, already tried experimentally, should become standard practice. This was agreed by the Air Staff, and put into effect as from the night of 22/23 September.

Thereafter, the production of Window for use against the Wurzburgs grew steadily and by the beginning of November the estimated consumption appeared to be well covered by the projected production. As production grew and new types of Window came in, it was possible to give more consideration to the packing of the material for the greater convenience of aircrew, and various alterations were considered in consultation with the Bombing Development Unit (B.D.U.) and the appropriate Service branches for the wrapping of individual bundles, the packing of bundles into convenient cartons or parcels, and the provision of launching chutes in aircraft. It should be mentioned here that the B.D.U. had been directed to carry out launching trials in consultation with T.R.E., and the design of special chutes was considered by the Unit. In this work the O.R.S. representative at B.D.U. was able to play a large part.

The consideration of the effects of Window was continued together with appreciations of the effects of tactical countermeasures which had been made necessary by the changing enemy fighter tactics. The methods continued to

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(1) A.H.B./IIK/46/468.

be those employed for the initial analyses. Bomber Command O.R.S. Report No. 80 covered August and Report No. 88 (1) carried on the story to 19/20 November. It was considered on the evidence of enemy R/T traffic that G.C.I. was still attempted but that Window continued to prevent its application to bombers in the main concentration.

In November an attempt was made to estimate the saving of aircraft which could be ascribed to the use of Window. This was prompted by some labour unrest in the firms producing Window (~~produced by~~ caused a lack of understanding of the virtues of the innocent-looking material which they were handling. The estimate was of course extremely speculative. It was based on the fact that losses in 1943, month by month on German targets, had been 0.5 per cent higher than they had been in the corresponding month of 1942. It was assumed that had Window not been used this trend would have continued, and that the losses in the Window-using period would have been 0.5 per cent higher than those of 1942 but for the use of the counter-measure. The actual loss rate was 1.5 per cent lower than the expected one estimated on this basis, and it therefore appeared that every seven tons of Window used had saved an aircraft. This conjecture was widely published as a fact on factory posters.

Window Against Air Interception (A.I.) Equipment

The continued success of enemy free-lance fighters directed attention to the possibility of doing more to defeat the Lichtenstein A.I. When estimates of the necessary Window release rates were made in the pre-operational period, it was considered that practicable rates of release could have little more than a nuisance value to an A.I. operator who had had a little practice with Window. Since that time a specimen of the Lichtenstein had fallen into British hands and the important information about its performance and the possibility of conducting experimental flights with it allowed the problem to be re-examined with more confidence. A note was prepared setting out the expected concentrations of Window estimated as necessary ~~as~~ on an arbitrary criterion that half the time-base must be filled with Window echoes to reduce the effective range of the apparatus to various degrees. The concentration of Window suggested as

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(1) A.H.B./IIH/258/1/14.

necessary to produce a serious effect were well in excess of those produced operationally, except possibily over the target. It was, however, pointed out that there was no real knowledge of what proportion of the time-base must be filled by Window echoes in order to make the set unusable, the Window concentrations needed in space must remain speculative. Proposals were therefore made for experiments with the captured Lichtenstein which would produce the required knowledge, and these were forwarded to Air Ministry with a request for speedy action on the trials.

Unfortunately, the projected trials suffered long delays owing to the unserviceability of the equipment or of the aircraft carrying it. Increase in the Window discharge rate was continually postponed, pending the trials results, although the trebling of the bomber concentration by increase in the rate of bombing from November 1943 onwards, and the restoration of the Window discharge rate to one per minute on the outward journey in mid-December, did something towards bringing the Window concentration towards that estimated as necessary for neutralising the Lichtenstein.

During May 1944, information was obtained that the enemy was using a new A.I. believed to be working on a frequency in the region 160-180 mc/s. In consultation with the Signals branch it was decided that immediate countermeasures should be prepared. There was a possibility of adapting Mandrel as an electrical jammer, but the technique of preparing long Window had just been mastered and O.R.S. examined the possibility of using such material against the new A.I. (Report No. B.210 'The Use of Window against A.I. on 150-170 mc/s').[1] It was assumed that the A.I. would have somewhat similar characteristics to the known enemy tail-warning apparatus - the Neptune R.gerat, and on this basis it was estimated that a launching rate of four bundles per minute would be necessary to black out the time-base at ranges of one mile and above. It was considered, however, that the maximum rate of launching by hand which could be accomplished, since launching of the anti-Wurzburg Window had to be carried on at the same time, would be one bundle per minute per aircraft for most of the route, and two bundles per minute for limited periods. It appeared that this rate would give a useful degree of interference and an estimate of the quantities required for the coming months was prepared, based on the usual assumptions

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(1) A.H.B.2 unindexed.

of target, distance and scale of effort. The project was agreed by the Signals branch, and a request was passed to Air Ministry for production to begin on the scale of the estimate.

In June 1944, while the trials were still receding into the future, discussion of interference with the Lichtenstein was again roused by a paper from the Deputy Director of Science which re-stated the view long since put forward by O.R.S. that a release rate of at least five bundles a minute was necessary. It was pointed out to the Air Staff that a sufficient stock of Window was held to permit an increase in the discharge rate, that the weight of the newer types of Window necessary for high discharge rates was, although high, not prohibitive and that the real obstacle to high rates was the ability of the crew to maintain them. It was agreed that a rate of discharge of five bundles per minute or as near to it as crews could manage should be tried over specified areas. The areas for high discharge rates were defined by the O.R.S. after examination of the positions of interceptions reported by crews during the preceding period.

Unfortunately, the trial began in mid-June when the lightness of the night sky made the use of an A.I. almost unnecessary. In any case there followed within a month the discovery that the enemy was replacing the Lichtenstein B.C. by the S.N.2 and further measures had to be sought.

Long Window

In July an intact specimen of the S.N.2 fell by a fortunate chance into British hands, and it then became known with certainty that the new enemy A.I. was working on a frequency of 90 mc/s. The stocks of Window prepared for the 150-170 mc/s band were of course not suitable, but the decision that a low frequency A.I. could be combatted with Window remained and a limited stock of Window Type M.B. prepared for use against Freyas was available. No fresh estimate of the concentration of Window required to combat the S.N.2 was made. The quantity of Window available in any case limited the amount that could be used. It was considered that a release rate of one per minute by half the bombers would produce a useful effect and could be met by existing stocks until new production became available.

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The use of long Window against A.I. began on 23/24 July. No analysis other than a comparison of losses and combats with those of comparable previous operations could reveal the effect of a countermeasure against A.I. The almost simultaneous military advance which gave fresh scope to the Mandrel screen and to other methods of defeating the enemy's early warning system rendered such a comparison difficult to interpret over a long period. However, the evidence provided by the aircraft losses on the first few operations using the long Window left little doubt that a serious blow had been dealt to the effectiveness of enemy fighters.

Although the use of Window was introduced as soon as the general characteristics of the new A.I. were known, it was decided to confirm the effects of the countermeasure by a flight trial with the captured specimen of the device. The trial was also designed to investigate the potentialities of the enemy's Flensburg equipment for homing on to the bomber tail-warning device Monica. The details were worked out by the Signals branch in consultation with the O.R.S. and interpretation of the results obtained was left to the O.R.S.

The plan of the trial was that 100 bombers would fly at heights between 15,000 and 18,000 feet at a speed of as near 160 R.A.S. as practicable on the route Cambridge, Gloucester, Hereford, Cambridge. The earlier stages of the flight were essentially Flensburg trials and will receive full treatment when Monica is discussed. On the final leg, Hereford - Cambridge, however, half the aircraft were to release one bundle per minute of Window Type MB and a fighter equipped with the S.N.2 was to make attempts to intercept bombers at different parts of the stream. In order to permit assessment of the concentration reached by the force, arrangements were made for photographing the P.P.I. tube of a G.C.I. station and of an Air Ministry Experimental Station Type 11 which would observe the bombers along part of their route. In addition, the aircrews were asked to log accurately the time and height at which their aircraft reached the turning points.

The flight was made by 71 bombers on 30 August 1944, and the analysis of the results obtained was presented on 5 September in Report No. S.175, 'The Trials of Flensburg and S.N.2 Against a Bomber Stream'.(1) The effect

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(1) A.H.B./II/39/1/1.

of Window on the P.P.Is of the ground equipment was rather serious at the time when photographs were taken and, although an attempt was made to isolate the responses due to Window by observing their rates of movement from successive photographs, no count of aircraft was possible. The photographs, however, yielded a reasonable measure of the width of the bomber stream. The times at the turning points recorded by all aircraft allowed an estimate to be made of the length of the stream and of the distribution of aircraft along it at the various stages of the flight.

The average concentration of bombers during the Window/S.N.2 stages of the trial was estimated as 0.4/cubic mile, a value similar to that believed to be obtained on night operations. The S.N.2 was completely blacked out by Window except at the head of the stream. It was concluded therefore, that the rate of release used, although below estimated theoretically as necessary, was adequate for operational use.

Thereafter, the development of Window against S.N.2 followed normal lines. Assistance was given through the Window Panel in developing more efficient types and the appropriate branches at Command were kept informed as to the best use which could be made of the several types. The stock position of the M type Window had to be watched carefully, and in changing over production to the more efficient types, care had to be taken that the loss of production in the transition was not too great. In such matters O.R.S. consultation with the M.A.P. branches was frequently needed.

Assessment of the effects of Window against S.N.2 was prevented by the operation of many other powerful factors. It was therefore uncertain whether the amounts dropped were remaining sufficient and when production had been built up sufficiently an increase in the rate of discharge was recommended and accepted. This recommendation was, of course, made purely on judgement of the situation based on the knowledge that the initial rate of dropping could have been barely sufficient for success and that the enemy operators were now well experienced in working through Window and the probability that the enemy would have developed ameliorative technical measures.

One important point common to the use of all types of Window was given special consideration in connection with the use of long Window

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against A.I. Tactical considerations in August 1944 suggested that heavy bomber forces attacking one target should fly on two or more separate routes. Such a scheme would of course have an effect on Window protection. The head of a bomber stream is never surrounded by a sufficient density of Window to give full protection, and the development of more than one head of a stream must increase the proportion of aircraft in positions with deficient Window cover. The effect insofar as it concerned the use of Type M Window against A.I. was considered quantitatively ('A Note on the Effect of several routes on the Concentration of Type M Window ORS/BC Internal Memorandum No. 142). (1) It was shown in this note that the maximum Window concentration likely to be developed in any bomber stream, at the existing rate of dropping and with the presumed standard of navigational accuracy, was unlikely to be more than adequate to impair seriously the usefulness of the enemy's A.I. It was then pointed out that if those separately routed forces were timed to bomb in five minutes, the maximum concentration of Window would only be reached at the tails of the streams but that if the whole of the force was in one stream, bombing over 15 minutes then two-thirds of the force would have the maximum Window cover. This argument was taken into consideration thereafter in the discussion of tactical handling of the bomber force.

The Threat of Centimetric Radar

At the end of 1944 evidence was accumulating that the enemy was developing centimetric radar equipment. T.R.E. were unhopeful of meeting the threat with electrical jamming, and Window appeared to offer the only prospect of a quick counter. The probable rates of discharge required were reviewed, assuming that the German centimetric gear would have similar characteristics to our own. It was estimated that a rate of discharge of 20 bundles per minute could be regarded as a minimum requirement, and that limitations in the capacity of aircraft and in the ability of the crew to discharge would limit the period of Window protection to 30-40 minutes. It was pointed out, however, that since the enemy would probably use a frequency in our own 10 cm band, our centimetric equipment would be interfered with by the use of Window. It was also suggested that so long as hand-launching of Window was necessary, use of centimetric Window should

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be confined to chosen parts of the route where half the force should change over, the remainder continuing to discharge the other types. At the concentrations then being achieved this reduction in the rate of discharge of the Wurzburg and S.N.2 Window appeared to be without grave risk, especially if electrical jamming of S.N.2 was available. The rate of discharge recommended for centimetric Window was ten bundles per minute, this being considered sufficient to cause some confusion in an A.I., although allowing it a useful range to complete black-out. On this basis the Command requirement for centimetric Window was estimated as two million bundles per month. This estimate was agreed on and put to Air Ministry. Then followed many discussions on how to meet the requirement at the Window Panel and with M.A.P. officers. The steps taken affected the Command only insofar as it was considered desirable to cease the use of centimetric Window on Bullseye exercises. It is not necessary to give details of the other measures taken but it may be mentioned that at the close of the European war the Command had been made able to use countermeasure Window against centimetric equipment appearing anywhere in the band 7-12cms.

Window Feints - Preparatory Work

The use of Window as an aid to feint operations has been referred to in the section dealing with Mandrel and special variants of this use are dealt with in the section on Operation Overlord. It is appropriate to deal here with some aspects of this important application which are specifically concerned with the fundamental properties of Window.

The need for feint operations in support of the re-entry into Europe stimulated the development and production of a form of Window (Type MB) capable of producing aircraft responses on the enemy's early warning sets. At this time (April 1944) the provision of Mandrel was well below that necessary to cover the bomber force against the enemy early warning system, and there appeared to be no prospect of improvement in main force fittings. There was, however, a prospect that a small number of aircraft would be equipped with jammers covering the whole frequency band of the known

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enemy early warning sets. The various possible combinations of Window and Mandrel were discussed in Report No. S.148 'The Possible uses of Freya Window and Mandrel against the Enemy Early Warning Equipment.'(1) It was considered that three objects should be aimed at: concealment of the approach of the bomber force along the early stages of the route, prevention of accurate plotting of the force, and interference with Freya-aided G.C.I.

In order to study the possibility of concealment of approach, a map showing the positions of enemy coastal radar stations and their estimated coverage was prepared. It appeared that to conceal the position of a force at a distance of 50 miles from the enemy coast by means of Window an area of at least 100 x 100 square miles would have to be infected with the Window echo every two square miles. It was estimated that 50 aircraft would be necessary to lay such a screen, whereas there was a good prospect of producing a more effective Mandrel screen with 20 aircraft. Window, however, concealed the size of the force and could therefore serve in the simulation of large scale attacks by means of small forces. The combination of such feints with the use of a screen of Mandrel aircraft was considered to offer excellent possibilities of confusing the enemy's plotting. The amount of Window and the number of aircraft required to produce a successful feint had to be estimated from first principles. The estimate was based on the characteristics of the enemy early warning sets as the proposal did not envisage that the feints would approach within range of precision radar. The argument ran that to simulate a force of 400 aircraft at least 400 Window echoes must be produced during the length of 'life' of the Window, taken as 10 minutes and that the echoes must be spread over an area likely to be occupied by such a force. This area was taken as 60 miles long and 20 miles wide and therefore it was considered that 200 echoes were required every 10 minutes in each of two consecutive 30 mile lengths. It was argued that Window bundles dropped closer together than the pulse length of the Freya would not give separate echoes, and that in order to avoid the appearance to the enemy radar of a series of separate trails, the separation of aircraft across the stream should not be less than two miles. On these bases it was estimated that

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a force of 25 aircraft each releasing two Window echoes per minute would be adequate. Since two bundles of Type MB Window were required to produce one aircraft echo, this was equivalent to a release rate of four bundles per minute. As, however, the feint force would leave a trail of dying Window echoes, the main force ought also to leave such a trail, and that therefore a few aircraft towards the head and the tail ought to release long Window on the approach to enemy territory.

For the flight over enemy territory it was estimated that the use of Freyas for G.C.I. purposes at ranges of 20 miles or more could be prevented if the density of echoing bodies was one per two square miles. It was considered, therefore, that the density of bombers alone should be sufficient to prevent the use of Freyas for G.C.I. except on the fringe of the stream. The possible extra protection which could be given to aircraft on the fringes by the use of long Window had to be weighed against the interference with Monica which would be caused and the additional effort involved by discharge of more Window. Judgment was given against the use of Window. The concealment of the direction of flight of the force over enemy territory clearly could not be achieved by Window and it was therefore considered that release of long Window by the main force would not be worthwhile except as mentioned above, on the approach to enemy territory in order to prevent distinction between main force and feint.

The recommendations were agreed by the Air Staff and a more detailed investigation was then made into the best methods of employing a Mandrel screen and Window-aided feints. Some particulars of this investigation were given in the section of this report dealing with Mandrel and the results were presented in O.R.S. Report No. B.216 'Proposals for the Tactical Use of the Mandrel Screen'.(1) It is necessary to refer here only to a slight change introduced into the Window release proposals. In examining the coverage of the enemy's coastal radar, it was considered that an effective feint force would need to approach within range of the Giant Wurzburgs. The recommendation was made, therefore, that the aircraft of the feint force should release Window covering the frequency band of the

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(1) A.H.B./IIM/a1/4a App. O.R.S.

Wurzburgs as well as that of the Freyas, Hoardings and Chimneys. The point was also made that any electrical jamming would readily be perceived by the enemy radar, and that therefore Mandrel and Carpet (the Wurzburg jammer) should be carried in the feint forces covering the same frequency ranges as the similar equipment in the main force.

Window Feints - The Operational Use

When No. 100 Group began to operate the Mandrel screen and Window feints, the principles laid down in the O.R.S. reports were followed. In the course of the preparation of the second report (No. B.216) discussions were in fact carried on with No. 100 Group. The number of aircraft available for feint forces was, however, always below the number of 25 which had been suggested as necessary, and an attempt was made to compensate for this by increased rates of Window release.

The success of Window feints could only be judged by the enemy's reaction to them as obtained from intercepted fighter control communications. This source of information was carefully watched, and after six weeks use of the feints a joint appreciation was prepared by O.R.S. No. 100 Group and O.R.S. Bomber Command. The apparent success of the feints was considered in conjunction with the variations in application, e.g. number of aircraft taking part, area of operation etc. The results (Report No. S.172 'First Operations of the Mandrel screen and Special Window Forces')(1) were inconclusive. It appeared that the feints were most successful when aimed at an area which the main force had been attacking in the immediate past at the time when the attack was switched to another area. Otherwise there was no apparent systematic cause of success or failure. Recommendations for improvement had therefore to be based on the deficiencies suspected from first principles. They were to increase the number of aircraft taking part and to include in the feint force aircraft equipped with all the radiating devices carried in the main force. It was also recommended that trials of a Window force against captured enemy equipment should be carried out. As aircraft and equipment became available, these recommendations, which put into writing what had probably been in many minds, were acted on although it was not until March 1945 that a trial against a captured enemy Freya was carried out.

(1) A.H.B./II/69/284.

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The evidence for the success of Window feints was kept under review but no definitely systematic variation was revealed. There were, of course, many factors, such as the navigational accuracy of the Window forces, which could not be taken into account. A final appreciation was presented at a meeting of the Operational Research Committee on 'Tactical Aids to the Defence of Bombers against Night Fighters and A.A. Fire' on 16 March 1943 (Report on Bomber Command Tactics attached as Appendix to the Minutes of the Meeting).(1) The conclusion was that the Window feints had had many successes but sometimes appeared to be correctly appreciated by the enemy, and that the best chance of success was obtained when the Window force broke away from the main force after flying with it until within range of the enemy radar.

Liaison and Propaganda Work

In spite of the long period of development, Window made a rather sudden impact on the Command organisation when it was introduced. This was largely because of security measures in force before the introduction of the countermeasure, but the effects of the impact was enhanced by the fact that there were no precedents for the control of a measure such as Window. As a radio countermeasure Window was clearly a sphere of influence of the Signals branch but the technical problems involved were remote from those to which that branch was accustomed. The discharge of material from an aircraft was akin to practices of the Armament branch but the material itself was quite unlike the material handled by that branch. After a brief experience, the Armament branch at Bomber Command handed over responsibility for Window launching to the Engineer branch. The use of Window called for special tactical planning which of course involved the Air Staff. Finally, a large volume of expendable material had to be handled and thereby imposed on the Equipment branch in a large new burden.

Thus many branches were concerned with different aspects of Window, and the O.R.S. concerned with all the aspects drifted into the position of a central information exchange. This position became recognised officially when the Command representation on the Window Panel was delegated to O.R.S. This panel was formed under the chairman ship of Wing Commander D.A.Jackson (T.R.E.) to investigate means of stimulating production and of improving

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the efficiency of Window, and to consider the development of new types. Its work will be discussed later.

One important duty which fell to O.R.S. was the keeping of a record of the Window stock. During the first few months of the use of Window the threat of exhaustion of supplies was always very real. Therefore, every morning the consumption of the previous night's operation was estimated by measuring the track mileage flown within the Window release area and doing the necessary arithmetic. The production during the day was estimated as one-seventh of the previous week's total production and from this figure and the night's consumption the nett change in the stocks was derived. The stock figure was checked weekly by returns from units holding stocks, and there were many anxious occasions when investigation into discrepancies was necessary. The rendering of stock figures long survived any need for it, and the Air Staff only consented to the cessation of the daily rite in May 1944 when more than ten million bundles of Window were held. It may be mentioned that the unit Window quantity most employed originally was the ton. This unit became meaningless when more than one type of Window became available, but so attached had the many interested parties become to the measure that it became customary to express quantities in 'equivalent tons' - the weight which the Window would have if it were all made in the form of the original type. This remarkable unit unfortunately gave the impression to many that Window was a mystery to which only scientists could have the key.

The Window Panel

It was mentioned earlier that the Command representation on the panel responsible for the development of Window material was made through the O.R.S. Since the work of this panel contributed very extensively to the success of Window a further reference to it is desirable. At the time when the panel was constituted (September 1943), initial stocks of Window were being exhausted and shortages of aluminium foil, paper, machines and labour were menacing production. Moreover, the launching of the existing type of bundle from aircraft was beset by troubles which concerned both the make-up of the bundles and packages and the arrangements within the aircraft. A considerable programme of exploration of

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new sources of supply was therefore necessary, and the panel acted as the necessary co-ordinating authority. Initial meetings were held weekly, later less frequently, but until the end of the European war the frequency of meetings of the panel was never less than monthly. The panel reported periodically to full assemblies at Air Ministry of all the parties interested in the production and use of Window. These were usually attended by Service representatives from Bomber Command in addition to the O.R.S. Decisions of the panel were, however, normally put directly into practice and only policy changes awaited confirmation by the full assembly.

The technical aspects of Window development were, of course, the concern of the appropriate M.A.P. branches, and the testing of products and of launching chutes was conducted by T.R.E. and B.D.U. Bomber Command's principal concern on the panel was to ensure that the required frequency coverages should be provided, that methods of packing and the weight and bulk of material should be such as to minimise difficulties of discharge, and above all that the required quantities should be forthcoming. Samples of paper, of boxes of strips, and of forms of packing were examined in large numbers and considered in relation to information gathered from aircrews about operational difficulties. Later, when methods of packing had been almost standardised, the need to meet quickly the changing demands for new forms of Window became the most pressing problem. This became acute when the threat of enemy centimetric equipment emerged. At this stage another small planning group was formed as a sub-committee of the Radio Countermeasures Board of Air Ministry. The aim of this sub-committee was to examine possibilities of making fundamental changes in the Window operation in order to meet the centimetric threat. Command representation on it was through O.R.S. Plans were formulated and the appropriate bodies delegated to develop the projects. This development was still in progress at the close of the European war.

Launching from aircraft was also a concern of the panel, and in January 1943 the principles of what was later built as the Fairey automatic launcher were evolved in discussion.

It is, of course, impossible to assess individual contributions to a body such as the Window panel which depended on discussion and the pooling of ideas. The achievement of the body as a whole was, however, noteworthy, and is reflected by the great progress made. In extremely difficult circumstances Window production was built up to a sufficiently high level to meet any likely demand, and at the same time was sufficiently flexible to meet rapid changes in demand. The form of Window insofar as it affected security of packing and ease of launching was improved enormously. In addition, considerable economies in the use of metal foil and paper were effected - the weight of aluminium in 1,000 bundles of anti-Wurzburg Window was reduced from 600 lbs to 51 lbs and the weight of paper from 1,100 lbs to 220 lbs.

Propaganda Work for Window

The need for propaganda in the Window factories in 1943 and how it was met by quoting the saving in aircraft and crews has been referred to previously. Propaganda amongst the users and amongst the controllers of supply of materials also became necessary. As the aircrews who had seen the first effects of Window finished their operational tour, they were replaced by others who carried out Window dropping as a routine, without understanding its purpose. Inevitably, such a routine was neglected by some, and when scraps of information from the squadrons revealed a rather widespread ignorance a short account of the way in which Window produces its effect, the need for care in launching and an outline of its influence on the enemy defensive system was prepared for the Air Staff as a simple guide for the instruction of aircrew in Report No. B.209 'Some facts about Window' April 1944.(1) This report was sent by the Air Staff to groups with a suggestion that suitable extracts should be made and distributed down to squadron and flight commanders. Although it served a useful purpose by spreading correct information, the process did not go far enough. Therefore, after the introduction of long Window, a revised simplified and shortened

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(1) A.H.B./IIH/258/1/50

version was prepared as 'More about Window' in August 1944. This included a sim le diagram of the appearance of Window on a radar presentation with indications of the failures likely to arise from a faulty use of Window, sufficient in itself to explain the use of Window to the impatient reader. This report was circulated as a whole down to squadrons by the Air Staff.

The many types of Window which had come into use by the summer of 1944 were also causing confusion at all levels of the Service branches concerned. In an endeavour to clear this, a catalogue of Window was prepared, listing the many types with an indication of the make-up of these bundles, and their purpose, together with an introduction summarising the reasons for the multiplication of the number of types. These documents were issued as Report No.B.220 'Types of Window'.(1)

At the beginning of 1945, the apparent approach of the end of the war caused some of those responsible for the provision of materials to look to a reduction in Window production as a possible immediate economy. One of the results of this was a proposal to remove Window from the list of 'designated' products, the effect of which would have been to lose some necessary priorities including that of labour. The O.R.S. was asked for information on the value of Window to combat this proposal. Examples were given of the successful use of Window in its four functions; interference with radar-controlled flak and searchlights, interference with G.C.I. carried out with Wurzburg, Freya or Jagdschloss, interference with A.I. and the production of spoof attacks. It was possible to point to the continuously lower flak damage rate since Window was used, to the total escape of the force on some nights when a G.C.I. system would have exacted a considerable toll, to the success of Type M against S.N.2 and to examples of successful Window feints. The proposals to regard Window as no longer fully essential were defeated.

The Launching of Window From Aircraft

Hand-launching

The problems of packing and wrapping for Window bundles have already been mentioned. The provision of facilities for the hand-launching within the aircraft was essentially an engineering problem, but it was one in which

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(1) A.H.B./IIH/241/10/195

O.R.S. had to take a general interest since the outlet used was from the beginning tied up with the form of the Window bundle and later determined the type of Window which could be used. Therefore, from October 1942 onwards participation in discussions and observation of trials concerning launching were carried on for about a year when the B.D.U. completed the design of a cowled chute which would permit satisfactory launching of all types of Window. Thereafter, apart from special consideration for aircraft taking part in Window feints in the Overlord operation, the main concern of the O.R.S. with hand-launching was to advise on the distribution of types of Window in order to ensure that aircraft used only the types for which their chute was suitable.

Automatic Window Launching - Development

It was always intended that hand-launching should be replaced quickly by automatic launching and long before the use of Window became an immediate prospectand even before the rates of discharge and the size of bundle had been decided the requirements for an automatic launcher were considered. The several possibilities of launching rates were given to the Air Staff, and it was suggested that the requirement for an automatic launcher should embrace all of them. The capabilities required on this basis were stated as a rate of launching variable between one and 30 pounds per minute and a capacity without reloading of 100 pounds. The design of automatic launchers had made little progress by the time the operational use of Window began. Then a period of intensive exploration revealed many technical difficulties. The O.R.S. acting as a liaison section in this as in other Window commitments, maintained contact with the various parties concerned in order to keep alive a sense of urgency and to ensure that the requirements of the Command were met. These requirements had been re-stated in accordance with the more definite estimates of the rates of release and total amount of Window prepared after the operational introduction of the countermeasures as:-

Capacity	... ...	1,000 bundles
Release Rate	... ...	Variable from one bundle in two minutes to six bundles per minute; the rate to be capable of selection in the air.
Size of Bundle	... ...	Up to 45 cm long and 7 cm diameter.

Several designs of launchers were examined and one of them reached the stage of extensive trials by B.D.U. at the end of 1943. The results of

these trials were discussed at a meeting of the Window Panel on 5 January 1944. It was decided that the faults of the machine made it unacceptable, but in the discussion the basis of design for a new type of launcher was evolved. The B.D.U. set to work on this basis and rapidly developed the design, the O.R.S. representative at the unit giving considerable assistance. Within three weeks a stage had been reached when the co-operation of the Fairey Aviation Company could be called for in order to bring the machine on to a possible production basis.

The period of development which followed was long and troublesome. The newly formed Operational Requirements branch at Bomber Command took over the responsibility of urging on the development and the role of the O.R.S. became one of advising what adjustments to the Command's original requirement could be accepted. These involved mainly the total capacity of the launcher and release rates for newer types of Window. In general, reductions on the original specification were advised in order that production should not be delayed, but no compromise on the maximum rate of launching of the Wurzburg/Lichtenstein Window was considered acceptable. In fact, when it appeared possible that a supply of launchers might be supplied from American sources it was recommended that a rate of launching of ten bundles per minute should be possible 'in order to be prepared ..... for a measure of deconcentration'.

By November 1944, there appeared good prospects that automatic launchers would be available for operational use in the course of a month. The immediate result was to provoke a mild flurry within the Command since the setting up of a special organisation on each operational station had to be envisaged. The problems were discussed at a meeting at Headquarters Bomber Command called by the Air Officer Administration on 11 November 1944 at which it was necessary for O.R.S. to urge once again that Window was an operational necessity and that its most efficient use demanded automatic launching. This meeting decided that an operational trial should be carried out in order to decide the magnitude of the organisational problems involved.

The production of operationally suitable models of the launcher was, however, further delayed, and in January 1945 it seemed that the introduction would be preceded by two other introductions which had a strong

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bearing on the usefulness of the machine. These were the provision of the Glenn-Martin mid-upper turret in the bombers and the development of a centimetric A.I. by the enemy. The considerable obstruction in the fuselage brought about by the turret would have made the bulk of the magazines of the launcher extremely undesirable and the rates of release required to counter a centimetric A.I. were far beyond the capabilities of the existing machine. The position had therefore to be reviewed and at a meeting at Air Ministry held on 25 January, the Command representatives intimated that the Fairey launcher could no longer meet the Command's requirements.

Air Ministry requested a new appreciation of the Command's requirements. A note was therefore prepared by the O.R.S. after consultation with the Air Staff and Signal branch. This note summarised the probable future requirements for Window launching in the European and Far Eastern theatres, and pointed out how the existing design of automatic launcher would fail to meet them. It was proposed that the operational trial with the existing design should proceed in order to obtain information useful in future design, but that development of types better able to meet requirements should be pursued with vigour. The note 'Automatic Window Launchers for Bomber Command' over the signature of the Chief Signals Officer, was circulated before a meeting at Air Ministry on 2 February. At this meeting it was agreed that new designs, including those of semi-automatic types and of externally carried machines, should proceed. The Command was asked to submit revised requirements. After a general outline had been sent to Air Ministry by the Operational Requirements branch, a more detailed statement clarifying the Command's position was drafted by the O.R.S. and was forwarded by the Operational Requirements branch. This statement urged the development of a hopper type of launcher to be re-loaded occasionally in flight. It was considered that such a design offered the best means of making possible high rates of discharge without the need of storing the large bulk of Window required in one fixed mass.

Automatic Launchers - Operational Trials

When there appeared to be a good prospect of being able to carry out the projected operational trial with the Fairey Launcher, a note was

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prepared setting out what were considered to be the objects of the trial, how they should be attained and the preparatory action needed to organize the trial. This note ('Memorandum on the projected trials of the Fairey Mark I Automatic Window Launcher at Little Staughton') was discussed at a meeting of representatives of the Air Staff, Signals, Operational Requirements and the O.R.S., and formed the basis for the organization of the trials. The squadron selected for the trial was No. 582 of the Pathfinder Force, at Little Staughton. The squadron was visited by representatives of the Air Staff, and the O.R.S. and arrangements for the trial were completed. These included the stationing of an O.R.S. representative at the squadron for most of the duration of the trial.

Installations of the launchers commenced during March 1945 and an O.R.S. representative paid visits to the squadron to observe the difficulties experienced and to advise on procedure. When the organisation had settled down the representative stayed at the squadron and it was also arranged that a party from the Air Ministry Manpower Research Unit should attend in order to record the time and labour consumed in servicing the launchers. The O.R.S. officer supervised the work of this party, inspected launchers after operations, discussed its performance with the aircrews and maintained appropriate records.

The results of the trial were presented in Bomber Command O.R.S. Report No. 134 'The Operational Trial of the Fairey Mark I Automatic Window Launcher'.[1] They included an analysis of the recordings made by the Manpower Research Party which established the labour needs for servicing the launcher, an estimate of the transport required, detailed analysis of the numerous failures which occurred and comments on the crews' reactions. Altogether the results provided a depressing picture and formed in fact a final condemnation of an already discredited type of launcher.

Carpet — CAPS

The need for a jammer for the enemy's Wurzburg apparatus used for control of flak and fighters was recognised as of the highest degree of urgency from the time of first knowledge of the enemy equipment. The

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(1) A.H.B./II/69/175(D)

technical difficulties were, however, considerable and it was not until the end of 1943 that T.R.E. was able to offer in Carpet II a jammer suitable for use in the British bomber force.

Carpet II included a search receiver which could sweep a band of frequencies 50 mc/s in width pre-selected from the range 450-600 mc/s. When an incident pulse was received on a frequency within the band being searched, the jammer tuned on to it and jammed it for a time which could be pre-set for any period between a few seconds and five minutes. The time for a complete searching sweep was one and a half seconds.

By the time that the device was at a stage when quantity production could be contemplated, Window was being used with success to counter the Wurzburgs and consideration had therefore to be given to the decision whether or not the addition of the electrical jammer would be worthwhile. An O.R.S. appreciation of the position was prepared at the request of the Signals branch (Report No. S.119 - 'The Possible Uses of Carpet II in Bomber Command').(1) The effects of Carpet with and without the additional use of Window on G.L. and G.C.I. operation were considered together with the probable enemy reactions. The scale of fitting with Carpet to produce the best results was also estimated. Technical data supplied by T.R.E. was available concerning the expected effect of a Carpet on one Wurzburg, but the effect of mutual support of both bombers and Wurzburgs had to be estimated using assumptions of their distribution in space.

Although Carpet had certain advantages over Window in regard to weight and bulk and the manipulation required, it was considered to have less flexibility in regard to volumes of production. It was suggested, therefore, that the two countermeasures should be regarded for the time being as complementary. Carpet appeared well suited to provide cover in circumstances where Window was least effective, e.g. at the head and fringes of the bomber stream and in operations by small forces. Taking the long-term view, however, there seemed to be a possibility that the concentrated raids necessary for the use of Window might become tactically disadvantageous and the greater tactical freedom which would be provided by the complete equipment of the

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(1) A.H.B./II/39/1/1.

force with Carpet would then be most valuable. The recommendations made were therefore that provision should be made for equipping the whole heavy bomber force with Carpet, priority being given to the Pathfinder Force and and specialist radio countermeasure aircraft who were most likely to have to fly in zones of reduced Window cover. The Command policy was stated to Air Ministry on this basis.

Introduction into Operations

Sufficient equipment was available by March 1944 to begin fitting the Pathfinder Force. The method of employment was discussed with the Signals branch. The period of jamming which each set should hold before resuming search for new frequencies had been recommended as two minutes in Report No. S.119 mentioned above. This period seemed a reasonable compromise between the prevention of ordinary radar plotting and the denial to the enemy of a useful D/F on the source of jamming. It was accepted for operational use, with the proviso that it should be reviewed later in the light of experience.

The Wurzburg frequencies were known to be spread over a band 100 mc/s wide, whereas each Carpet set could only search a band of 50 mc/s. Since initially there appeared to be too few sets available to provide mutual support, each set had to be used to cover as many Wurzburgs as possible. Therefore, it was decided that each set should search the same frequency band. This was selected as 530-580 mc/s which, according to Intelligence information, would include the greatest number of Wurzburgs.

The Carpet sets were fitted with an indicator light to show when the set was jamming and crews were requested to log the times and duration of periods of jamming in order that the need for any change in the jamming period or the frequency search band might be perceived.

The first reports made by crews showed that many sets were jamming almost continuously. This was rather more than had been expected from what was known of the distribution of Wurzburgs and an O.R.S. officer visited the squadron concerned to interrogate the crews. There appeared to be no doubt that the reports were justified and a probable explanation was considered to be ~~that the reports were justified and a probable explanation was~~

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explanation was considered to be that the receivers of the sets were too sensitive and that the jamming was therefore being applied to Wurzburgs too distant to obtain useful radar plots. A check of the sensitivity confirmed this and after discussion with T.R.E. a maximum sensitivity for the setting of the receivers was agreed on. This change produced results more in accordance with expectation, although the non-jamming periods remained few and short. Another modification introduced as a result of T.R.E. tests was a reduction of the width of band searched to 40 mc/s, 540-580 mc/s being chosen.

Statistics of the casualties to Carpet carrying aircraft were collected and after ten weeks operational experience a survey of the results was made (Report No. B.215 'A Note on Initial Operational Experience with Carpet II'(1)). The numbers of missing aircraft were rather too small to permit a satisfactory assessment to be made. Numbers of aircraft damaged by flak were somewhat larger, and since, in view of the decline in enemy G.C.I., the use of Carpet was expected to produce its most marked effect on gunfire control, these numbers provided a reasonable basis for consideration.

It appeared that the use of Carpet had been associated with an appreciably lower risk of flak damage, an impression which was confirmed when the categorised severity of the damage done was considered. Thus, there was some indication that Carpet could provide some protection for aircraft carrying it. An attempt was made to assess the general effects of the device on the parts of the bomber stream in which it was carried. Two thirds of the Carpet using sorties had been briefed to bomb in the early stages of a raid. A comparison was made therefore between the losses of main force aircraft planned to fly in the front of the bomber stream and those planned to fly at other parts. None of these aircraft was carrying Carpet. It was shown that since the introduction of Carpet, losses for all parts of the stream except that in which the jammers were concentrated had risen.

Interpretation of this result was complicated by variations in the enemy fighter tactics which had considerable influence on the relative losses of

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(1) A.H.B./IIM/a1/4a App. O.R.S.

different parts of the bomber stream and it could only be regarded as promising. Thus, although the limited amount of evidence accumulated in ten weeks experience could not permit a final assessment of the value of Carpet to be made, it all tended to give a favourable impression of the device. As with most of the other radio-countermeausre devices, action on production could not wait for statistically significant results; judgement had to be made on the impression gained and the recommendation was made that the fitting of Carpet should be extended throughout the force. The argument that such fitting would permit greater tactical freedom in handling the bomber force was regarded as strengthened by the promising results. The recommendation was accepted and the Air Ministry was asked to endeavour to arrange for the whole bomber force to be fitted with one set per aircraft by the winter of 1944-45, and to make provision for two sets per aircraft as soon as possible in order to give greater frequency coverage.

Later Operational Results

The promise of the early results was not fulfilled by subsequent experience. As the scale of fitting and the numbers involved in comparative assessments increased, it became more difficult to discover that Carpet was producing any effect on the casualties of aircraft carrying it. Trials with captured equipment had shown that the performance of Carpet could be improved. There was some tendency for the sets to lock off frequency when activated by a strong signal, and also the aerial used with the set was not to the design best able to produce a maximum jamming signal through the Wurzburg aerial which could be made selective as to plane of polarisation. The indecisive results obtained with Carpet were marshalled and put forward to the Signals branch as an incentive to urge the technical improvement of Carpet ('Carpet II; Statistics of Losses and Flak Damage' C.R.S. internal Memorandum No.) (1) As a result, Air Ministry was requested to arrange for the modifications necessary for the improvement in Carpet with a minimum of delay. The modification designed to improve the accuracy of locking to frequency was carried out in the course of the next few months, but fitting of the most suitable form of aerial was never accomplished.

/Fitting

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Fitting was extended to include in addition to the Pathfinder Force, some squadrons of Nos. 3 and 5 Groups which were frequently obliged to fly at the head of a bomber stream. The operational statistics for each of the three Groups were examined in great detail, but no consistent effect of Carpet could be perceived. The enemy Wurzburg band was extending, no doubt as a result of jamming and the 140 mc/s band to which the Carpet search was confined was no more densely populated by Wurzburgs frequencies than at least one more band of equal width. Moreover, the aircraft not protected by Carpet had Window cover against the Wurzburgs. It was not expected, therefore, that a very appreciable benefit from Carpet would be perceived. The U.S.A.A.F. was also using Carpet in a form suited to the protection of its bomber forces and discussions on the results obtained were carried on from time to time with the O.R.S. of the Eighth Air Force. The American results were also rather inconclusive but it appeared likely that some effect was produced when the jamming of the whole Wurzburg frequency band was made more complete. There was evidence from captured documents and equipment, interrogation of Prisoners of War and other Intelligence sources that the enemy was expending effort on measures to combat jamming.

The use of Carpet II was therefore continued and fitting was extended. Arrangements were made to spread the jamming over an 80 mc/s band and, as a check on the relative needs of the two 40 mc/s bands chosen and on the general performance of Carpet, counters were, at the suggestion of T.R.E., fitted to some of the sets. These counted the number of times which the sets stopped searching and jammed during an operation. The results obtained with the counters were analysed as they became available. It was soon apparent that some of the counts obtained were larger than could be produced by two minute jamming periods without searching periods through the whole operation. It was thus possible to indicate from the counts that the setting up of some of the jammers was probably incorrect. The approximate equality in the jamming effort expended on the two 40 mc/s search bands could also be demonstrated. The use of counters was therefore considered to be worthy of extension. It was hoped by use of them and by experimental changes in the sensitivity setting of the Carpets to determine the best

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~~sensitivity setting of the Carpets to determine the best~~ setting as the high number of jamming periods counted on an operation indicated that the sets might still be activated by Wurzburgsat too great a distance. More counters were provided, but the end of the European war came before they could be used with profit.

A final review of the results obtained with Carpet failed to reveal that the device had been beneficial to the aircraft which had carried it. Thus the use of another device had been carried out and extended on judgement only without statistical evidence of success. This was fully justified since, owing to the incomplete cover of Wurzburg frequencies by Carpet, the simultaneous use of Window and the general deterioration of the enemy defences during its period of use, an effect large enough to be revealed by the usual numerical comparisons was not to be expected. On the other hand, the accepted need to be prepared for operations with forces less concentrated than were suitable for the use of Window and the knowledge that the enemy was being obliged to spend effort on trying to avoid jamming at a time when his resources were contracting made the countermeasure of Carpet desirable so long as no adverse effect of the risks of aircraft carrying it could be perceived.

Signals Silence — Cahs

Preliminary Considerations

In January 1944, Intelligence had established that the enemy was activating I.F.F. sets left switched on in bomber aircraft and was using the resulting transmissions to obtain early warning of the approach of a raid and to plot its course. This was relatively easy to check by ensuring as far as possible that no I.F.F. sets were switched on. By June, however, it had become known that the enemy was also obtaining information about bomber movements by plotting the source of other radiation including that from the R.C.M. equipment, tail-warning devices and the navigational aid H2S.

There was also a suspicion that enemy fighters were being equipped with devices which permitted them to home on to bomber's transmissions. Radiation from bombers could not of course be stopped without loss of the

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benefits conferred by use of the radiating devices, and this loss had to be weighed against the probable saving likely to result from denial of their use to the enemy plotting system.

This was not a matter in which quantitative balances could be struck and much discussion resulted within the Command and with T.R.E. on the probable performance of the enemy listening equipment. There was one rather doubtful piece of evidence from analysis of operational data. In one operation which involved two targets, the two forces differed considerably in the proportion of aircraft using H2S. The force making most use of this device was much more heavily engaged by enemy fighters than was the other, and it was considered that the fighter controller might have assessed the relative importance of the two raids on the basis of the radiation picked up (Report No. B.213 'Report on Losses in Night Operations 21/22 June 1944, Wesseling - Scholven').(1)

The general problem was fully discussed at a meeting of the Operational Research Committee on Tactical Countermeasures to Enemy Night Fighters and A.A. defences on 11 July, 1944. The primary purpose of this meeting was to consider measures which would assist the protection of thebomber force during the winter 1944/45. T.R.E. put forward suggestions that the bomber force should no longer be flown to the target in a compact stream but should be used in a much reduced concentration in space, reliance being placed in electrical jamming to counter the enemy's Wurzburgs and A.I. ('Aids to the Bomber Offensive during the winter 1944/45, Part I, Bomber Losses' 23 June 1944 - paper submitted by Chief Superintendent T.R.E. to the O.R.C. Sub-Committee. The Bomber Command O.R.S. view was that the possibility of fighters homing to bomber radiations could defeat such a scheme. The jammers carried for the bombers' protection would themselves become homing beacons, and it appeared very doubtful if jamming of the enemy A.I. would be sufficiently effective to prevent its use for completing an interception initiated by homing. Air Staff represented that H2S was an essential aid to navigation and since if this device were used there was little point in ceasing the use of other radiating devices, the Sub-Committees conclusion was that the

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(1) ~~A.H.B.2 unnumbered.~~ A.H.B./258/1/299.

Command should be prepared to vary its tactics as much as possible, careful watch being kept on the losses of aircraft carrying radiating equipment.

The First Firm Recommendations

Almost immediately afterwards anxiety was increased by the sure confirmation that the enemy had equipped a proportion of his fighters with devices which would permit them to home on to transmissions from the tail-warning device Monica or from the navigational aid H2S. An appreciation of the dangers of the enemy development and of the possible countermeasures was prepared jointly by the Signals branch and O.R.S. for the guidance of the Air Staff (Report No. B.218 'An Appreciation of the Use by the Enemy of Transmissions from our Bombers').(1)

It was clear that there were four ways in which the enemy might profit by his receivers; gaining early warning by ground listening, plotting the course of the bomber stream by ground listening, homing fighters into the bomber stream by use of airborne receivers, and homing on to individual bombers by use of airborne receivers.

Of these threats only the last one, homing on to individual aircraft, could be assessed by reference to operational statistics. It was possible to show that aircraft using Monica or H2S had loss-rates similar to those of otherwise comparable aircraft without the devices. For Monica this might mean that the benefits from use as a tail-warning were being cancelled by the disadvantages of being homed on and the need for seeking safeguarding measures was emphasised.

In order to deny the enemy early warning from transmissions, it was clearly necessary to stop all radiation until the force was within expected range of the enemy's normal radar system. Since H2S serviceability was likely to be adversely affected if switching on was delayed until the aircraft were at operational height, it was considered that immediate orders to delay transmission were inadvisable, but that the modification of the H2S sets necessary to permit switching on at any time should be regarded as urgent.

Enemy plotting of the bomber force over territory in his occupation was possible by means of his own radar and his Observer Corps. Therefore,

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(1) ~~A.H.B.2 withdrawn.~~ A.H.B./IIM/a1/4a App. O.R.S.

although additional aid was given to him by bombers' transmissions it was considered that such aid should not outweigh the advantages to the bomber force resulting from the use of radiating devices.

The possibility of fighters homing onto the bomber stream was, however, regarded as a much more serious menace. Communications between the fighters and their ground control had always been regarded as a link in the enemy defence chain most vulnerable to countermeasures, and the use of homers threatened to make such communication almost unnecessary. It was recommended that should the use of Monica continue to give results which suggested that the risk of homing onto individual aircraft could be tolerated, the using aircraft should be employed as a separate force in order that unfitted aircraft should be spared the attention of fighters homing onto the stream.

Some use of H2S., e.g. in target marking and for intermittent checks on navigation, was considered to be essential but it was suggested that trials should be carried out to ascertain how far the use could be restricted, and that the development of an additional aid, Loran, should be accelerated. A recommendation was also made that in order to assist in assessing the homing danger, the aircraft using H2S should occasionally be sent to the target on a route separate from that of aircraft not using the device.

Finally, since it was envisaged that complete protection against homing in to the stream was unlikely to be achieved, attempts to deceive the enemy by use of simulated bomber transmissions in Bomber Support night fighters and to accelerate the development of the bombers' radar aid to blind firing, Automatic Gun Layer (Turret) (A.G.L.(T)) were recommended.

The Restriction of Monica

Before the proposals had been discussed fully with the Air Staff, preliminary flight trials of Monica and a captured specimen of the enemy's Flensburg homer provided evidence that anxiety about the ability of the fighters to home onto a Monica using bomber stream was fully justified, and that homing onto individual aircraft was also to be feared. Views on the future of Monica were, after further O.R.S. Signals discussions, re-stated to the Air Staff. It was re-affirmed that Monica if used at all should be confined to forces wholly equipped with the device, and that its complete

withdrawal should be considered. A full-scale trial of a large Monica equipped force against Flensburg was recommended as a guide to a final decision. Such a trial was carried out. Details are given in the section of this chapter dealing with Monica and all that is necessary to state here is that the demonstration of the effectiveness of Flensburg which it provided led to a decision to abandon the use of Monica from 12 September, 1944.

The Case for H2S

After this, apart from H2S and a small amount of A.G.L.(T), the radiating devices carried were jamming and communications equipment which need not be used until enemy territory was reached and could be dispensed with altogether if clear knowledge of an associated homing risk was obtained. The question of restricting radiation along the early stages of a route became, therefore, concerned with the use of H2S. The arguments relative to the enemy's exploitation of the H2S transmissions had been clearly stated in the Signals/O.R.S. memorandum to the Air Staff, with the conclusions that urgent consideration should be given to preparations to allow the device to be switched on at operational height close to enemy territory and to experiments designed to assess the need for and the effect of restrictions on its use over enemy territory. Many who had been associated with the development and use of H2S felt that the value of the device was being underestimated and that any restrictions in its use even if not directly harmful would, owing to anxiety induced in aircrews, lead to a decline in the use of the device and a consequent reduction in the success of bombing operations. There was therefore an acute division of opinion. It was not possible to make a quantitative assessment of the merits of either side and the Command attempted in July and August to treat each operation on its own merits, frequently applying restriction in the use of H2S on the approach to enemy territory. The advance of the allied armies had, however, by mid-September seriously disorganised the enemy's early warning radar system and had thereby given increased importance to the need for preventing the use of bombers' transmissions for long range plotting. The use of H2S was therefore restricted along the early stages of the route for nearly every operation.

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Although no action was taken by the Command to explore the effects of restriction on the use of H2S over enemy territory, individual groups put their own interpretation on the information available to them about the enemy's homing devices and applied considerable restrictions on radiation. For No. 5 Group these involved the almost complete cessation of the use of the nine centimetre H2S Mark II and restrictions on the use of three centimetre H2S Mark III. This was of course disturbing to those who regarded H2S as an essential aid to accurate navigation and bombing. They argued that even if successful results were obtained temporarily on raids which were not penetrating deeply into enemy territory the expected decline in training and in general interest in H2S would have serious effects on future operations.

The Command Policy Decisions

On 22 September, a Bomber Command conference fully representative of the many branches and establishments within and outside the Command discussed the issues in an attempt to arrive at a firm line of policy. The O.R.S. view put to the meeting was that there could be no question of the necessity to delay switching on H2S on the approach to enemy territory. The military advance had in addition to disrupting the enemy's radar system made possible the use of the navigational aid Gee nearly up to the enemy's frontiers, thereby making the use of H2S on the early stages of the route unnecessary as well as undesirable. Homing on to individual aircraft or into the bomber stream by the use of H2S transmissions were regarded as menaces not requiring immediate action but calling for consideration and preparation. The only argument advanced against this policy was that the delayed switching on of H2S on every operation regardless of the height of approach would involve an increase in the unserviceability of the equipment and the modifications necessary to avoid the risk were likely to take some months to accomplish. The conclusion reached was that the justification for this anxiety should be sought in experience and that H2S should not be used outside enemy radar range when alternative navigational assistance was available.

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The matter was further discussed at a meeting of the Command Tactical Planning Committee on 30 September. The O.R.S. submitted a map of the coverage now provided by Gee in support of the contention that the use of H2S was unnecessary, until the enemy frontier was approached.

The conclusion of the R.C.M. policy meeting was confirmed and the policy became firmly established that the navigational aid on the approach to enemy territory should be Gee for as great a distance as was possible, H2S only being brought into use in time to obtain a good fix before running out of Gee range. Other transmissions, except that from the blind-firing aid A.G.L.(T) were also restricted and the approach of the force without use of its radio and radar equipment became established as a radio countermeasure, known briefly as 'Signals Silence'.

The Case of A.G.L.(T)

A.G.L.(T) was a special case because there were greater difficulties in switching on this device at operational height than there were for H2S. Special consideration was given to it, and it was concluded that so long as the number of sets in the force remained small, radiation could be permitted since the enemy's ability to distinguish by listening between a small number of aircraft carrying A.G.L.(T) and intruder fighters carrying A.I. Mark X was doubted (Report No. 226 'The Possible Exploitation of A.G.L.(T) transmissions for plotting and Homing').(1)

Signals Silence in Operation

The adoption of 'Signals Silence' as a routine operational instruction did not stop controversy, largely because independent lines of action were still pursued by the groups who were not until 13 October, i.e. three months after the first measures to restrict radiation, provided with an authoritative explanation of the Command policy. This explanation, prepared in collaboration by the Signals and O.R.S. branches and issued over the signature of the Deputy Commander-in-Chief pointed out the great advantages to be gained by denying early warning to the enemy in the 'Signals Silence' approach, but pointed out that no information was available from operational statistics or other sources that homing by fighters onto individual aircraft

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was possible. Restrictions on the use of H2S exceeding those laid down by Command were, however, still ordered, particularly by No. 5 Group which was usually operating alone.

The evidence provided by intercepted enemy fighter control radio traffic showed clearly that from September onwards the range of the enemy's first plots on the bomber force was much reduced. Information on the nature of the first plots wss not, however, sufficiently good to enable an assessment to be made of the relative contributions to this result of 'Signals Silence', in view of the disruption of the enemy's early warning radar chain by the military advance and improvements in operation of the Mandrel screen.

Comparative statistics on casualties continued to give no cause for anxiety about enemy homing onto individual H2S carrying aircraft, and the general reduction in casualties suggested that homing on to the stream was not being accomplished on anything but a small scale. On the other hand, there was no reason to suppose that the Groups' restrictions on the use of H2S had an adverse effect on the success of their operations and an examination of the track-keeping and time-keeping after the introduction of 'Signals Silence' showed that they were similar to those obtaining when H2S was in full use. Although the advice given to and accepted by the Command Air Staff had been against some of the restrictive actions of the Groups, the inclination was to regard these actions in the light of useful experiments since a more severe general restriction had to be visualised as a future requirement.

The Command's policy in this matter was still considered to be unsound in a number of high quarters, and it was agreed that a full investigation into the operation of radiation restrictions should be undertaken by a senior officer of T.R.E. His report, although agreeing that the Command policy was justified, tended to the view that action had originally been taken on insufficient evidence. This, intended as criticism, was in effect a compliment for always in the radio war it was necessary to act quickly on judgements supported by inadequate evidence, and in this case there was absolutely no doubt that the judgement had been correct.

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Radio Countermeasures in Operation Overlord — Cairo

Introduction

The re-entry to the Continent in 1944 was clearly an enterprise which called for maximum efforts to achieve surprise. Since a principal agency against surprise was the enemy radar system, an elaborate plan of destruction and deception was prepared against that system. The general requirements for Radio Countermeasures in support of the landing operations were laid down by the Naval and Air Staffs concerned in consultation with T.R.E. and others, but much of the detailed planning of the R.C.M. operations necessarily devolved on Bomber Command, at that time the only Command having large-scale experience of R.C.M. and possessing the required devices. This detailed planning was the responsibility of the Signals branch, but at all stages of the preparation the programme was discussed by a joint Committee of Signals and O.R.S. staff.

A full account of the plan finally prepared and successfully carried out has been given elsewhere.(1) Briefly, the plan involved the simulation by means of Window released from aircraft of convoys approaching two parts of the coast, the provision of a Mandrel screen to cover the approach of airborne forces, simulation of airborne forces by Window and the jamming of enemy V.H.F. communications by means of A.B.C. The mode of operation of the Mandrel screen and of the A.B.C. aircraft was settled in discussion between Signals and O.R.S. representatives. The methods used were essentially those used in planning the Mandrel screen for bombing operations (Report Nos. S.148 (3) and B.216).(2) The development of the schemes for Window feints called, however, for a specific study by O.R.S.

Window for Operation Overlord - First Proposals

The requirement for the use of Window originally made was to supplement electrical jamming in order to black out the enemy radar observation of three areas in the Channel, and to provide cover for the airborne forces. These projects were duscussed at T.R.E. who had been concerned with the broad plan and had proposed many of the schemes, and a detailed scheme was then prepared (Report No. B.202 - 'An Estimate of the Window and Aircraft required to provide cover requested by A.E.A.F.'). It was considered that

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(1) A.H.B.Narr. The Lib. of N.W. Europe, Vol.III.
(2) A.H.B./II/69/175(B) and A.H.B./IIM/a1/4a App.O.R.S.
(3) ~~A.H.B. reindexed.~~

the best means of producing a complete black-out either for the concealment of surface forces in the channel or for covering the approach of the air-borne forces was to release Window in sufficient quantity to produce a dense cloud of dispersed dipoles rather than to rely on filling the time-base of the enemy radar with discrete echoes from individual bundles as was the practice in bomber operations. The T.R.E. recommendation was that in order to achieve this effect, four times the amount of Window needed to fill the time-base with discrete echoes would have to be released. A calculation was therefore made of the Window density required to fill the time-bases of the enemy coastal radar installations, Giant Wurzburg, Freya and Seetakt, situated in the most favourable position, for observation with the discrete echoes at the shortest range at which black-out was required. This density multiplied by four was then assumed to be the density to be aimed at for complete black-out.

The areas required to be blacked out were 20 x 15 miles, but it was considered that this should be increased by ten miles in each direction to allow for navigational error and wind drift of Window. It was estimated that the Window released from one aircraft would cover a lane of width three miles, and that therefore to cover the required front of 30 miles, ten lanes of aircraft would be required. Since renewal of the Window was required every 15 minutes, the total distance to be covered in 15 minutes was double the depth of the area (25 miles) for each of 10 lanes. 10 aircraft flying at a true airspeed of 200 m.p.h. would thus be just able to deal with one area, flying along paths three miles apart to and from the coast, releasing Window on the runs towards the coast.

It was estimated that each aircraft would need to discharge Window bundles at the following rates per minute; 72 for Wurzburg frequencies, 12 for Freya frequencies, and 6 for Seetakt frequencies, i.e. 90 bundles per minute for all types. Although it was suggested that the rate of release could be made practicable by packing the Window so that the equivalent of four bundles could be released simultaneously and by providing additional crew and launching positions, the total quantity of Window to be carried by

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each aircraft for the screening of the Naval forces was estimated at 2,275 pounds, occupying a space of 55 cubic feet. The amounts required for the screening of the airborne forces were somewhat less, but were still formidable. It was recommended that the stowage and launching problems be explored immediately.

It was decided by the Air Staff that Wellington aircraft of the O.T.Us should, if possible, perform the operation because a full effort from the bomber force would be required for other purposes. An O.R.S. representative therefore, visited an O.T.U. to investigate the stowage and launching problems in the Wellington. Trials of Window stowage and launching were carried out under conditions of flight similar to those expected on the operation. It was concluded that subject to a few minor modifications to the aircraft and to the packing of the Window, the proposals made were wholly practicable. A revised version of Bomber Command O.R.S. Report No. B.202 was issued on 24th March, 1944, incorporating the proposals for stowing and launching resulting from the trials. Training for the operation began in No. 92 Group and, after some experience had been gained, various problems concerning navigation and the arrangements for training were discussed with the group representatives.

Plans had just been worked out when a revision of the part to be played by Window was proposed.

Window for Overlord - Final Scheme

Two of the areas in the channel which it had been proposed to drench with Window were not to be used by real assault forces but were intended as feints. It had been suggested by T.R.E. that realistic feints could be produced if Window were used to simulate naval forces. Initial opinions had not been very favourable to such a scheme owing to the high degree of navigational accuracy which would be required for its success, and the black-out shceme had therefore been developed. However, trials on a limited scale conducted by the Royal Navy and the Allied Expeditionary Air Force, with T.R.E. help showed that the scheme was by no means impractical. A request was made, therefore, to Bomber Command that such a plan be substituted for the one under active preparation. It was proposed in addition that the airborne forces should be protected by the use of Window aided feints instead of by direct screening.

The proposals were discussed between representatives of the Signals and O.R.S. branches of Bomber Command, A.E.A.F. and T.R.E. on 18 April 1944. The plan for simulation of a convoy which had emerged from the trials was that aircraft flying very accurately on elliptical orbits about 10 miles long releasing Window of appropriate type along the straight runs of the orbit, which were to be two miles apart and should at each successive orbit approach nearer to the coast by the distance which a convoy would move during the orbit time. In order to maintain the illusion of a surface force the sizes of Window bundles were to be adjusted as the orbitting aircraft approached the coast in order that the size of echoes produced should vary in accordance with the change in echoing power of surface targets with distance. It was agreed that arrangements would be made to try out the proposed scheme. These were to include the provision of a radar site suitably equipped and situated relative to Gee lattice lines similarly to the operational area. The O.R.S. was asked to prepare a detailed scheme for the aircraft flights and Window release.

The broad outlines of the type of flying and accuracy of navigation required were discussed with No. 92 Group on the basis of the experience gained in this training for the initial scheme. It appeared that the use of Wellington aircraft with O.T.U. standards of navigation would not permit a scheme wherein each aircraft completed an elliptical orbit and an alternative plan was prepared which involved an accurate run along a Gee lattice line in one direction only. This of course doubled the number of aircraft required. A further increase in number of aircraft was necessitated by the fact that three boxes of orbitting aircraft were required in order to produce the desired length of 'convoy' instead of the two boxes hoped for. It was, however, considered thatfurther trials should be made with a view to retention of the elliptical orbit.

The size of Window bundle required at the several stages of the simulation was estimated from T.R.E. reports on the echoing properties of surface targets. It was estimated from reports on the initial trials that the operation could be performed with six sizes of bundle, a schedule of the

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times for release of bundles of the appropriate size was prepared, and the total requirements for the various sizes of bundle was calculated. Suggestions were made for packing this special Window in ways which would facilitate the change over from type to type in the aircraft.

Similar estimates were made for the planned simulation of airborne forces. The results of these considerations (Report No. B.206 'An Estimate of the Window and aircraft required for the Revised A.E.A.F. Plan' - 22 April 1944) (1) were forwarded by the Air Staff to SHAEF.

T.R.E. also gave consideration to the problem (Report No. 5/M91/RC 'Use of Window to simulate low level targets in enemy radar' - 28 April 1944) (2) They suggested that sufficient navigational accuracy would be achieved if the elliptical orbits were flown, and accurate fixes obtained only when the aircraft turned off the straight run, reliance being placed on accurate turning to position the second straight leg of the orbit. The T.R.E. proposals for Window bundle sizes differed immaterially from those made in the O.R.S. report which were already being acted on. The navigational problems were discussed between T.R.E. and O.R.S. and trials agreed on.

Meanwhile, discussions had been carried on at Bomber Command between O.R.S. and Signals which resulted in a conclusion that the Window feints required a navigational standard above that of the O.T.Us. Therefore, the recommendation was made to the Air Staff that, although simulation of the airborne forces could remain an O.T.U. commitment, the convoy simulation should be made the task of a three flight operational squadron. As a result No. 617 Squadron was nominated to prepare for the convoy simulation. The Squadron Commander was called into discussion at Bomber Command on 7 May 1944, the basis being an O.R.S. memorandum summarising the scheme laid down in O.R.S. Report No. B.206 and embodying the results of discussions with T.R.E. on the navigational problems. It was agreed that the necessary training should begin immediately, and that an attempt should be made within a week to decide whether the operation would be practicable.

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(1) A.H.B./IIM/a1/4a (22 Apr. 1944).
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An O.R.S. representative visited the squadron to explain and discuss the scheme with the navigators, assist in arrangements for training, and in the assessment of results. It was quickly apparent that although training flights could be made anywhere, assessment of the accuracy by means of ground photographs presented great difficulties, and it was recommended that the coastal radar site which had been allotted for trials of the simulation should be used throughout training. This was arranged, and it was soon shown that the squadron would be capable of performing the operation with the accuracy required. When this was established, the further development of the navigational technique was left to T.R.E., while O.R.S. paid more attention to the Window aspects. The development of several new types in addition to the special bundles for the convoy simulation was then going on in order to cover Seektakt and Freya frequencies and in order to have double units for use in high rates of discharge. Questions arising on the suitability of these types and of their packing for the tasks in hand, the production of the necessary quantities and their despatch to the correct destinations were a constant responsibility.

The method used by No. 617 Squadron relied entirely upon the navigational aid Gee. Since the operation was to be performed at low level doubts were felt about the reception of Gee pulses in the proposed operational areas. Test flights showed that in one of these areas, the doubts were fully justified. Means of overcoming the difficulty were discussed at Bomber Command and a possible solution appeared to be the use of a combination of Gee and another navigational aid Gee-H. This solution was adopted by the Air Staff, and the only squadron trained in the Gee-H technique, No. 218, was allotted the convoy simulation task in one area, No. 617 Squadron being left to cover the area in which Gee was adequate for the task.

The O.R.S. representative who had already been assisting No. 218 Squadron in Gee-H training was delegated to assist in the special training, and it was soon established that this squadron also would be able to perform the required operation. Thereafter, no major changes had to be made,

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although numerous points arose as the operational plan as a whole became more clear. These were normally settled in the Signals/O.R.S. discussions.

When the time came for the issue of final operational instructions, the O.R.S. prepared schedules of Window release and, in conjunction with T.R.E. and the Signals branch, prepared detailed navigational instructions for each aircraft, including the Gee and Gee-H co-ordinates required for the turning points of every orbit. The operations were carried through with every appearance of success, and as became known later contributed considerably to the surprise effected by the assault.

The simulation of airborne forces involved little preparation. The plan as laid down in Report No. B.206, with the amendments made necessary by changes in the places and times of operation, was carried through without trouble.