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ABSTRACT

This thesis explores the origins of the Radio War, which started in 1940, and explains how the United Kingdom came to fight a defensive campaign until 1942. In the first part of the thesis the Luftwaffe use of beacons and beams for navigation and bombing purposes is explored, together with the actions taken by the Royal Air Force to frustrate the Luftwaffe from using these aids and preventing the destruction of British cities and industry, which clearly would have been totally disastrous. The second part examines the reasons, which led the Royal Air Force in 1942 to adopt a more offensive posture in order to provide protection to allied bomber aircraft from the effect of the greatly improved German radar-controlled defences.

The thesis justifies the creation of entirely new formations to control the application of countermeasures and reveals how the headquarters of the new formations were provided with the latest German intelligence information, essential to their role. The thesis goes on to investigate the critical part played by British Research, with especial reference to the Telecommunication Research Establishment. The thesis demonstrates how the Royal Air Force was forced to create a radio countermeasure organisation at a critical time in 1940, at the beginning of the German bombing campaign against the United Kingdom, how the application of these measures helped to protect Royal Air Force bomber aircraft and later successfully assisted in D-Day deception and radio countermeasure plans.

THE RADIO WAR

WAGED BY THE

ROYAL AIR FORCE

AGAINST

GERMANY,

1940 - 1945

SUBMISSION DETAILS

THE RADIO WAR WAGED BY THE ROYAL AIR FORCE AGAINST GERMANY 1940-1945

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PhD

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One morning, over fifty years ago, I was sitting in the Intelligence Room at RAF Oulton, reading the after-raid reports from the previous night's operations, little realising that one day I should be in a position to write about the highly secret activities in which I was involved. In researching and writing this thesis I have been fortunate in the help and support I have received from my Supervisor, Professor Arthur Marwick. Without his advice, expertise and, above all, encouragement, it would not have been written. I should like to thank Dr Annika Mombauer for her suggestions and assistance and also Dr Christina Goulter for her helpful comments. I owe a debt of gratitude to Mr Peter Mapp of Devizes who has generously given his time and expertise helping me to present the thesis in the required format.

I wish to acknowledge the permission of the Controller of Her Majesty's Stationery Office to quote from publications and all official records in which the Copyright is vested in the Crown. I also wish to thank the Librarian of the former TRE Library at Malvern, now styled the Defence Evaluation Research Agency, for bringing the history of No 80 (Signals) Wing and Dr Cockburn's The Radio War to my attention, and also to the Chief Librarian of the Joint Services Command and Staff College, Mr Christopher Hobson, for confirming that both remain unpublished. I am also grateful to the Centre for the History of Defence Electronics (ChiDE) of Bournemouth University, which uses the latest information technology to convey technical and social history in a readily accessible way. Lastly I should like to thank Air Commodore D.M. Reader, a former RAF Signals Specialist, for his help and co-operation.

Devizes,
Wiltshire
July 2002 Peter Lovatt

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MAPS AND DIAGRAMS

GLOSSARY

A

AAEE	Aeroplane and Armament Experimental Establishment
ABC	Airborne Cigar. Countered German VHF communications on 38-42 Mcs and 30-33 or 48-52 Mcs
ACM	Aircraft Transmissions- Meaconing
Abdullah	The operation of homing on German Wurzburg radar stations
ADGB	Air Defence of Great Britain, (Fighter Command)
ADI(Sc)	Assistant Director of Intelligence (Science)
AEAF	Allied Expeditionary Air Force
AI	Air interception by means of radar carried in fighter aircraft
ALB-15	American British Laboratory, Division 15 (branch of Radiation Research Laboratories working at Malvern)
ASE	Admiralty Signals Establishment
Aspirin	Purpose built transmitter used as a jammer again Knickebein navigation and bombing beam
ASV	Air to Surface Vessel. Coastal Command search radar
AVM	Air Vice Marshal
Azimuth	Vertical arc from zenith to horizon; angular distance of this from meridian

B

Bagful	Automatic search receiver recording RF of signals and time of interception on tape, with Interchangeable RF heads supplied coverage over 20-2000 Mcs, later 20-6000 Mcs
Barbara and Barbarossa	Development of German Egon control system
Benito	German navigation and bombing beam system in which range is determined by measuring the change of modulation phase of returning signal. Frequencies 42.3-44 Mcs
Benjamin	Ground jammer to counter German Y-Gerät bombing beam
Bernhard	German navigation aid using rotating beam, telemetering is used for communicating to aircraft
Bernhardine	Aircraft equipment associated with Bernhard
Blond	Automatic search receiver recording photographically the pulse shape, pulse length, prf, RF, split speed and time of interception of received signals (Frequency coverage as for Bagful)
Bombe	An electro-mechanical device which helped in the breaking of Enigma messages brought in from the Y-Stations
Bromide	Ground jammer to counter German X-Gerät beam
BSDU	Bomber Support Development Unit
Boozer	RAF Aircraft receiver giving visual warning when held in German radar beam

C

Carpet	Airborne jammer to counter German Wurzburgs

Carpet II	Selective noise modulated jammer for 180-450 Mcs and 450-600 Mcs
Carpet III-IV	Various types of US barrage jammer
Chain Home	CH. Original UK Early Warning radar operating between 15 and 27 Mcs
Chimney	German long range early warning radar Frequency in the Freya band
CHL	Chain Home Low Flying. UK search radar operating on 200 Mcs
Cigar	Airborne selective jammer used against German night fighter ground control in 38-42 Mcs
Coalscuttle	Airborne D/F system for detecting signals on frequencies above 1000 Mcs
Corona	RAF HF ground jammer, used against control of Luftwaffe night fighters
CRDF	Cathode Ray Direction Finder
Crystal Control	An accurate method of controlling transmitter frequencies by means of crystals
CW	Continuous Wave

D

D/F	Direction Finding
Dartboard	RAF M/F jammer, used against broadcast instructions to Luftwaffe night fighters
DCAS	Deputy Chief of Air Staff
Deviator	An emergency jammer deployed employed against Knickebein, using a 50 watt standard RAF beam approach beacon
Dina(h)	US airborne high power jammer
Direction Finding	Method of establishing the bearing of wireless transmitter; two bearings will provide location

Domino	Counter to Benito. Signals from aircraft picked up and re-radiated on ground station frequency
Drumstick	RAF jammer used to disrupt Luftwaffe control channels in the 3-6 Mcs band
Duppel	German name for metal foil dropped to confuse radar. Duppel is a town near the Danish border, where RAF Window was first found

E

Egon	German blind bombing system using two Freya stations
Elektra	German navigation system, comprising a fan of equi-signal beams separated by alternate dots and dashes operating on 481 kcs
ELINT	Electronic Intelligence
Erstling	German IFF system (FuG 25)

F

Fidget	The employment of certain Meacon transmitters against German beacons broadcasting night fighter commentaries
Fighter Benito	Benito German navigation ranging system for use with Fighter-Bombers
Flensburg	German equipment for Homing on to Monica.
Freya	German Early Warning ground radar equipment, originally working on 125 Mcs but later over 75-180 Mcs
Freya Halbe	German equipment for Homing on to airborne Freya jammer

G

GAF	German Air Force, the Luftwaffe
GCI	Ground Control of Interception (Original RAF frequency worked on 209 Mcs)

Gee	British navigation aid. Aircraft position is obtained from the intersection of two sets of hyperbolae determined by three ground stations
Gee-H	UK blind bombing device. Aircraft equipment interrogated ground beacons and aircraft position obtained by intersection of two circles (the Gee indicator was used in the aircraft)
Geschwader	German Air Force unit, nearest equivalent to an RAF Group
Gruppe	German Air Force unit, nearest equivalent to an RAF Wing. Kampfgruppe 100 was an independent bomber unit and was often referred to as KG 100
GL	Gun-laying radar, British Army
Glimmer	Code name for seaborne invasion diversion to Boulogne
Grocer	RAF Jamming equipment for Lichtenstein AI radar

H

H2S	Airborne plan position equipment, which permitted identification of built-up areas and other landmarks (originally used 10 cms wavelength)
Headache	Generic term for measures to jam Knickebein navigation and bombing beam
Heidelburg	German technique for obtaining early warning using RAF CH transmissions
Heinrich	German ground jammer to counter RAF Gee navigation aid
H/F	High Frequency
Himmelbett	German system of close-controlled night fighting
Hoarding	German radar equipment for long range early warning (frequency in the Freya band)
Hohentwiel	German ASV working on about 500 Mcs

I

IFF	Identification Friend or Foe
IFRU	Intermediate Frequency Rejecter Unit – anti jamming device
Intruder	Fighter interference to enemy aircraft and airfields, normally at night

J

JG	Jagdgeschwader – German Fighter Wing
Jagdschloss	German 150 Mcs continuously rotating ground equipment, with PPI presentation, used for fighter control
Jostle	Airborne frequency modulated jammer for German R/T
Jostle II	Covers 24-54 Mcs
Jostle III	Simulated noise jammer using pulse modulation. Only one model produced
Jostle IV	High power frequency modulated jammer, covering 3-54 Mcs (used for jamming German night fighter R/T control and the V2, when a special variant was used)

K

Kampf-geschwader	KG. German Luftwaffe Bomber Unit equivalent to Royal Air Force Bomber Group
Kampfgruppe	KGr. German Luftwaffe Bomber Unit equivalent to Royal Air Force Wing
Kleine Heidelberg	Passive German ground system for aircraft detection, using reflected radiation from British ground radars
Knickebein	German navigation and bombing beam. Used frequencies between 30-33 Mcs

Korfu	German ground radar receiver which provided bearings to RAF aircraft using H2S

L

Lichtenstein	German AI on 90 Mcs, later 36.2-120 Mcs and 490 Mcs
Loran	US navigation system similar to Gee, but operating on 2 Mcs
Lorenz beams	Navigational aid employing a split beam to indicate a given track

M

Magnetron	Electron tube for amplifying or generating microwaves. The Boot and Randall magnetron evolved out of Hertz's original resonant ring, into a resonant cylinder and thence developed into a six-cavity system
Mandrel	Noise modulated Barrage jammer used against Freyas
Mandrel I	Airborne jammer covering 118-148 Mcs, in bands of 10 Mcs
Mandrel II	Airborne jammer covering 60-200 Mcs, in bands of 25 Mcs
Mandrel III	Modified IFF circuit (spot frequency noise jammer-receiving 15-200 Mcs band)
Mandrel V	Improved spot frequency jammer covering 30-600 Mcs
MB	Window, designed to cover 70-200 Mcs, Freya and FuG 220
Mcs	Megacycles per second
Meaconing	Spoiling German D/F transmissions by picking up and simultaneously re-radiating the original signals from a different location
Mimic	Operation to upset Luftwaffe radio beacons, especially when being used to pass information

Mimicry	RAF device causing Meacon transmitters to self oscillate against low-powered Luftwaffe beacons used by aircraft launching flying bombs against the United Kingdom
Monica	RAF tail-warning airborne radar equipment
Moonshine	Device which enabled one airborne aircraft to appear as a large formation in an enemy radar

N

Naxos	German equipment for homing on to RAF 10 cms equipment fitted to Bomber Command aircraft (FuG 350)
NPL	National Physical Laboratory, Teddington
Nuremberg	Modification to Wurzburg gun-laying radar to minimise effects of Window

O

Oboe	British blind bombing device using accurate ground control
Oculist	Luftwaffe W/T H/F broadcasts to night fighters
ORS	Operational Research Section
Oslo Report	One of the most remarkable intelligence reports of the second world war, sent anonymously to the British Naval Attaché in Oslo in November 1939. It lifted the veil of ignorance which surrounded Germany's most important scientific and technological advances
Ottakar	R/T instructions provided to Luftwaffe night fighters, initially on 31.2 Mcs

P

PDS	TRE Post Design Service

Perfectos	Device enabling British fighters to home on to emissions of German IFF equipment
Ping Pong	A wide band D/F equipment with accuracy of about a quarter of a degree
Piperack	Jamming equipment used against German AI (Lichtenstein SN2)
PRF	Peak Repetitive Frequency
PRO	Public Record Office, Kew
PRU	Photographic Reconnaissance Unit

R

R/T	Radio telephony
Radar	Radio Direction and Ranging
RAE	Royal Aircraft Establishment, Farnborough
Rayon	High-powered RAF transmitter used to overcome Ottakar
RCM	Radio Countermeasures
Rope	Non-resonant form of Window, 400 ft rolls of aluminium foil
RRDE	Radio Research and Development. Establishment at Malvern (formerly ADRDE) – Army
RRL	Radio Research Laboratories, Harvard, USA, responsible for research and development on radio countermeasures
Ruffians	British name for X-Verfahren

S

SAT	Scientific Adviser on Telecommunications. (Air Ministry)

SCR.720	US AI equipment similar to RAF Mk X
Schwan Buoy	Luftwaffe navigation beacons provided for He 111s of 1KG66, employed in air-launching flying bombs over the North Sea
Seetakt	German coast watching radar using 370 Mcs and gun-laying radar
Serrate	RAF airborne homing equipment used against German AI, Lichtenstein and SN-2 radars
SHAEF	Supreme Headquarters Allied Expeditionary Force
Shiver	Modified IFF set
SIU	Signals Installation Unit closely working with TRE
SN2	German AI equipment in 90 Mcs band, (later 36.2-120 Mcs)
Sonne	German rotating beam navigation system working on about 30-370 Kcs
Splasher	Bomber Command radio beacon
Stopper Patrol	Patrol off the entrance to port of Brest, France, organised by Coastal Command
SWF	No 100 Group Special Window Force

T

TAF	Tactical Air Force.
Tame Boar	Tame Boar GG. Emergency method of employing Luftwaffe twin-engined fighters in the night defence role
Taxable	Code name for invasion diversion to Cap d'Antifer
Tinsel	Airborne selective jammer of German night fighter control R/T link on 3-6 Mcs

TRE	Telecommunications Research Establishment
Tuba	US High-powered ground jammer, used to counter German Lichtenstein radar

V

V1	German flying bomb
V2	German long range rocket
VHF	Very High Frequency, in the RAF 30-300 Mcs

W

Wassermann	German early warning radar
WIDU	Wireless Intelligence and Development Unit
Wild Boar	Wild Boar. Emergency method of employing Luftwaffe day fighters in the night defence role
Window	British name for metal foil dropped to confuse German radar organisation
Windjammer	RAF name for Bernhard and Bernhardine
W/T	Wireless Telegraphy
Wurzburg	German ground radar equipment on about 53 Mcs, used to direct AA guns, searchlights and nightfighters

X

X-Gerät	Airborne apparatus associated with X-Verfahren

Y

Yagi	Type of aerial display developed by Dr. Yagi of Japan, exemplified by TV aerials utilised for the reception of UHF transmissions
Y-Control	German method of controlling nightfighters using modified Y-Gerät equipment
Y-Gerät	German beam used for navigation and blind bombing

VOLUME ONE OF TWO

THE DEFENSIVE PHASE

INTRODUCTION.

When Britain declared war on Germany in 1939, the United Kingdom little realised how much the Luftwaffe had come to depend on Medium Frequency radio beacons for navigation purposes, although it was aware of their existence and of their routine employment by Lufthansa, the national state airline, for such use in peacetime. What was not known, however, was the development of the three radio navigation and bombing beams, in the use of which German aircrews had already received, or were about to receive, appropriate training. No other air force in the world possessed such beams and thus, when the United Kingdom began to be attacked in earnest in 1940 by the Luftwaffe making use of these devices, it caused some consternation in London. The Royal Air Force reacted to the situation by seeking out methods with which to counteract them, firstly by masking the beacons with equipment already developed by the General Post Office, and then by attempting to jam the beam signals. Without suitable equipment to hand, however, makeshift measures had to be adopted against the latter, until purpose-built transmitters became available at a later date, from the Telecommunications Centre. During 1940 until early in 1942, the Royal Air Force fought a defensive radio countermeasure war against Germany. This period, the defensive phase of the early years of the war, is the focus of the first part of this thesis.

So important had the Benito countermeasures become by 1941 that the RAF considered it necessary to issue Secret

Benito Operations Reports from 8 March 1941 to 17 April 1941. These may be found in the Public Record Office at Kew, under the reference Air 40 Piece 2242 and provided much of the evidence on which this account is based.

From 1942 onwards, after the Channel Dash, when the German Battle Cruisers *Scharnhorst* and *Gneisenau* and Cruiser *Prinz Eugen*, successfully passed through the English Channel on their way to Germany, the situation changed. For the first time in the war, the Germans had jammed British radar and thus there were no longer the inhibitions and restraints which had formerly held back the Royal Air Force from such actions in the past. Until that point the British had been extremely sensitive over the Chain Home radar and thus restrained from interfering with German radar in any way. Moreover, Bomber Command was beginning to become a stronger and more effective force in the same year, 1942, which the United States Army Air Forces started to arrive in Europe, although some time was to elapse before the latter would be able to attack Germany effectively. But as bomber operations conducted by the Royal Air Force started to increase in size and tempo, losses began to mount due to effective German defences, which increasingly involved the use of radar, and radar controlled searchlights and guns and radar equipped night fighters. Consequently, in order to try to reduce the numbers of casualties, Bomber Command sought to employ the first of what was to be a range of airborne countermeasures. Ground measures had already been utilised for this purpose but invariably these were limited by range. Thus, the next step was to provide airborne equipment for the task. Unfortunately, some of the items were bulky and heavy and thus a weight penalty was involved; more protection – less range or bomb load. Eventually a compromise was reached, whereby some countermeasure protection was carried by a majority of aircraft, with the heavier equipment being allocated to special support aircraft dedicated to the provision of radio countermeasures. The period 1942-1945 thus marks the second stage in the evolution of the radio war, or defensive-offensive phase, in which ground and airborne equipment contributed to the radio war, and is the subject of Volume Two of this thesis.

1. Aims of the Thesis

From intercepted Enigma messages, and the interrogation of captured Luftwaffe aircrew, together with the aid of German maps and documents, the Royal Air Force confirmed that in 1940 the German Luftwaffe were using wireless beacons and beams for navigation and bombing purposes. The first aim of this thesis is thus to explicate the search for, and the finding of, these particular beacons and beams by the RAF. Once these beacons and beams were found and identified, the Air Ministry decided to take action in order to render them useless for the purpose intended. To be successful, however, such measures had to be controlled and applied in a logical manner. In order to be able to achieve this a new formation was created, No 80 (Signals) Wing. The second aim of the thesis is thus to examine the reasons why this Wing was formed, to investigate its organisation and operations; and to confirm how it was controlled.

In 1939 the Royal Air Force possessed little in the way of radio jamming equipment; if countermeasures were to be applied against the German devices in 1940, the Royal Air Force would have to improvise. Later on, dedicated jammers would be designed and made available. The third aim of the thesis is thus to trace the early and subsequent ground-based measures taken to nullify the German beacons and beams; and to determine just how successful No 80 Wing was during the defensive phase in the radio war.

Inevitably, the effects of ground-based jamming equipment were limited by range. In order to overcome this disadvantage thought was given to RAF aircraft carrying their own airborne jammers. At first Bomber Command was loath to adopt such measures, as indeed it had been, earlier, with radio navigation and target-finding equipment, for fear of disclosing the aircraft's position. It will be shown that rising losses, however, forced the acceptance of defensive radio equipment. Moreover, in 1942, the Germans jammed British radar to expedite the passage of their capital ships through the English Channel. This action enabled the RAF to adopt a more offensive stance in the radio war and to jam German radar. In order to control the defensive and offensive aspects of the radio war, the RAF decided late in 1943 to establish a new formation, No 100 Group, which would be responsible for all such measures, including the activities of No 80 Wing. The fourth aim of this thesis is to discover how and why this Group was formed, to investigate its organisation and to appraise the success and failure of its operations.

The Telecommunications Establishment (TRE) evolved out of previous Air Ministry Research Stations, associated with the development and provision of the radar chain, which provided warning of hostile aircraft approaching the United Kingdom; the Chain Home and Chain Home Low. TRE came to be responsible for designing much of the jamming equipment required by the RAF, and for producing many of the prototype transmitters. TRE also submitted a number of authoritative papers on future radio countermeasure policy to the RCM Board in London. The fifth aim of this thesis is to examine the contribution made by this research establishment to the radio war, and especially the assistance provided to the Bomber Offensive and the radio countermeasure plan implemented by the allies on D-Day, 6 June 1944.

2. Literature Consulted

A large number of unpublished primary sources were consulted in the writing of this thesis. Of particular interest in the Public Record Office was the lengthy, unpublished No 80 Wing Historical Report written by the staff officers concerned with No 80 Wing's activities in January 1946, with a Foreword by the then Officer Commanding No 80 Wing, Group Captain E.B. Addison.[1] In addition the unpublished monograph, The Radio War, written by Dr Robert Cockburn on the subject as seen from the Telecommunications Research Establishment's

[1] No 80 Wing, Royal Air Force Historical Report 1940-1945, PRO Air 41/46.

point of view proved invaluable.[2] Both sources have been consulted and quoted at length. No official history of No 100 Group has been published and no draft of one could be found in the PRO, and this thesis therefore fills an important gap. But an operational history has been written and published by Martin Bowman and Tom Cushing, which provides useful detail about the activities of the Group's Mosquito force.[3] A history of TRE has been written, but not published and a draft copy reposes in the former TRE Library at Malvern, now the Defence Evaluation Research Agency.

I found the registered papers belonging to the Department of Chief of the Air Staff under Class Air 8 helpful. Both Bomber Command's papers under Class Air 14 and Fighter Command's papers under Air Class 16 I found invaluable in understanding the radio war. The unregistered papers belonging to Class Air 20 was also essential reading. Classes Air 24, 25, 26, and 27 provided basic information about operations undertaken by the RAF Commands, Groups, Wings and Squadrons. Class Air 40 contained intelligence information concerning secret Benito activity and Class Air 41 contained Monographs and Narratives written by the Air Historical Branch, which are also essential reading if the radio war is to be understood. All of these may be

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[2] The Radio War, PRO Air 29/8953.

[3] Martin W. Bowman and Tom Cushing, *Confounding The Reich The Operational History of 100 Group (Bomber Support) RAF* (Patrick Stephens Limited, Yeovil, Somerset, 1996).

found in the Public Record Office at Kew, under the references furnished, and provide much of the evidence on which this account is based. Vital information about the Government Code and Communications Centre was obtained by reading Class HW 43, the Birch Histories. Classes Avia 7 and 26 provided much detail about the work of TRE. Appendix "E", the RCM section of the Harris War Despatch (PRO Air 20/1962) was especially informative about the development of Radio Countermeasures in Bomber Command.[4] F.H. Hinsley's*, British Intelligence in the Second World War*, 4 vols. was particularly revealing, Volume 1 providing much information about the Oslo Report, the GAF raid on Coventry and the breaking of the Enigma Code.[5]

From secondary sources the *Most Secret War* by Dr R.V. Jones is essential reading to an understanding of the whole campaign, as is *Instruments of Darkness* by Alfred Price.[6] RAF Bomber operations are comprehensively covered in Martin Middlebrook and Chris Everitt's excellent *The Bomber Command War Diaries* and Martin Streetly's *Confound and Destroy* provides much technical detail about No 100 Group, including

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[4] PRO Air 20/1962, Despatch on War Operations 23 February 1942 – 8 May 1945 by Air Chief Marshal Sir Arthur T. Harris, G.C.B., O.B.E., A.F.C. Air Officer Commanding-in-Chief, Bomber Command. But see also *Despatch on War Operations 23 February 1942 to 8 May 145,* by Sir Arthur T. Harris (Frank Cass, 1995)

[5] F.H. Hinsley, *British Intelligence in the Second World War*, 4 vols (HMSO, 1979) 1.

[6] R.V.Jones, *Most Secret War* (Hamish Hamilton, 1978); Alfred Price, *Instruments of Darkness* (Macdonald and Jane's 1977).

the American dimension and the bomber support campaign.[7] Air Vice Marshal Tony Mason in his *Air Power: A Centennial Appraisal,* provided useful information about the infant Royal Air Force and Luftwaffe.[8] The same author, Tim Mason, in his *British Flight Testing*, confirmed that aircraft from the Aeroplane and Armament Experimental Establishment were placed at the disposal of Orford and Bawdsey research stations from 1936, for the purposes of developing airborne radar.[9] Air Vice Marshal R.A. Mason in his *Air Power: An Overview of Roles*, endorses the importance of Early Warning.[10] As Tim Mason, in *The Secret Years,* he brings out the secretive nature of the work of the Wireless Investigation and Development Unit (later No 109 Squadron) whilst at Boscombe Down.[11]

The most comprehensive discussion of Hitler's strategic thinking is to be found amongst *Germany and the Second World War* edited by the Research Institute for Military History, Potsdam, Germany; volumes IV, *The Attack on the Soviet Union*

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[7] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries* (Viking Books Ltd, 1985); Martin Streetly, *Confound and Destroy* (Jane's, 1985).

[8] Air Vice Marshal Tony Mason, *Air Power: A Centennial Appraisal* (Brassey's 1994).

[9] Tim Mason, *British Flight Testing* (Putnam, 1993).

[10] Air Vice Marshal R.A. Mason, *Air Power: An Overview of Roles* (Brassey's Defence Publishers, 1987).

[11] Tim Mason, *The Secret Years* (Hikoki Publications, Aldershot, 1998).

and VI, *The Global War* being especially useful.[12] *The Rise and Fall of the Luftwaffe,* by David Irving, provides a good account of the fortunes of the German Air Force; while Gebhard Aders in his *History of the German Night fighter Force,* drawing on such archival sources as the Bundesarchiv/Militärarchiv, Freiburg, describes in detail some of the varying successes and failures of Bomber Command's attacks on German targets.[13] *The Luftwaffe War Diaries* by Cajus Bekker, translated and edited by Frank Ziegler, is based on interrogations of numerous wartime Luftwaffe leaders, and is useful in that it gives an overall view of the activities of the German Air Force in the west, including the period covering the Battle of Britain, the Night Defence of the Reich and the Battle of Germany.[14] Most helpful with details of the Luftwaffe Pathfinder beam operations over the United Kingdom was Ken Wakefield's *Pfadfinder* and E.R. Hooton in his *Eagle in Flames* which furnished information about German casualties and losses.[15] Donald L. Caldwell's *JG 26*, based on

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[12] Rolf-Dieter Müller, 'From Economic Alliance to a War of Colonial Exploitation' in Research Institute for Military History, Potsdam, Germany (eds.) *Germany and the Second World War,* Vol. IV, *The Attack on the Soviet Union,* and Werner Rahn, 'The War at Sea in the Atlantic and in the Arctic Ocean' in Research Institute for Military History, Potsdam, Germany (eds.) *Germany and the Second World War: Vol. VI, The Global War* (Clarendon Press, Oxford, 2001).

[13] David Irving, *The Rise and Fall of the Luftwaffe* (Little, Brown and Company, Boston-Toronto, 1973); Gebbard Aders, *History of the German Night fighter Force 1917-1945* (Crecy Books, Somerset, 1992).

[14] Cajus Bekker, *The Luftwaffe War Diaries* (Macdonald, 1966).

[15] Ken Wakefield, *Pfadfinder* (Crecy Books, Norwich, 1992); E.R. Hooton, *Eagle in Flames* (Brockhampton Press, 1999).

the recollections of fifty German veterans, provided an insight into the operations of the leading Luftwaffe fighter wing when it was based in France. His descriptions of the Channel Dash and the GAF response to the allied landings on D-Day were especially illuminating.[16]

Michael Howard's *British Intelligence in the Second World War: Finest Hour,* was useful in that Chapter 6 provided details about Operation Fortitude and discussed the lengths to which the British were prepared to go to mislead Hitler about the landing beaches on the Continent.[17] *Inside the Third Reich* by Albert Speer provided an insight into the way that Germany was governed and how he, Speer, dealt with shortages of armaments, aircraft and fuel, often at a critical time.[18] Stephen E. Ambrose's, *The Wild Blue,* provided an indication of the damage done to the German aircraft factories during Operation Big Week, as well as the grievous losses inflicted on the United States Army Air Force by the German fighters.[19] Reg Batt, in his *Radar Army*, provided the information that Metropolitan Vickers produced the Chain Home radar transmitters working on 6-15 metres and that A.C. Cossor of London produced the Chain

[16] Donald Caldwell, *JG 26* (Orion Books, New York, 1991).

[17] Michael Howard, *British Intelligence in the Second World War: Finest Hour,* vol.5, (HMSO, 1990) 5.

[18] Albert Speer, *Inside the Third Reich* (Weidenfeld & Nicolson, 1970).

[19] Stephen, E. Ambrose, *The Wild Blue* (Simon and Schuster, New York, 2001).

Home Receivers.[20] E.G. Bowen's, *Radar days* provided a useful insight into the early days of Air Interception, together with a fascinating over-view of the Tizard Mission to the USA and Canada, with its gift of the Magnetron and jet engine.[21] The beginning of No 80 (Signals) Wing, and the early radio countermeasures, are well described in Laurie Brettingham's *Royal Air Force Beam Benders, 80 (Signals) Wing, 1940-1945* using Air 26/280, 26/580, 27/853 and 41/46 as sources; and John R. Bushby's *Air Defence of Great Britain,* details some of the problems experienced in the United Kingdom when the Authorities tried to arrive at a fully integrated system of air defence.[22] The importance of the convoys to Russia and how crucial it was to keep Stalin in the war against Hitler is well brought out in Martin Gilbert's *Finest Hour.*[23] In *Barbarossa,* Alan Clark relates how perilously close the German army came to capturing Leningrad and possibly forcing Stalin to sue for peace.[24] The bombing of London, especially on the night 29 December 1940, is well documented in Basil Collier's *The Defence of the United Kingdom,* the main Ruffian beams used on

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[20] Reg Batt, *The Radar Army* (Robert Hale, 1991).

[21] E.G. Bowen, *Radar Days* (Adam Hilger, Bristol, 1987).

[22] Laurie Brettingham, *Beam Benders, Royal Air Force 80 (Signals) Wing 1940-1945* (Midland Publishing Limited, Leicester, 1997); John R. Bushby, *Air Defence of Great Britain* (Ian Allan, 1973).

[23] Martin Gilbert, *Winston S. Churchill Finest Hour 1939-1941,* 6 vols. (Houghton Miflin Company, Boston, 1983),6.

[24] Alan Clark, *Barbarossa: The Russian-German Conflict 1941-1945* (Orion Books, 1966).

that occasion being of special interest.[25] Aileen Clayton provides an early and fascinating account of the RAF Y-Service, and also describes the inter-change of information between Cheadle and Kingsdown in her *The Enemy is Listening.*[26] Alan W. Cooper well describes the use Corona and Airborne Cigar are put to, in his *Bombers over Berlin.*[27] The history of No 109 Squadron is portrayed in Michael Cumming's *Beam Bombers,* starting with WIDU, progressing through 109 Squadron and ending with Oboe operations in No 8 (PFF) Group.[28] Len Deighton in his *Blitzkrieg* discloses that the *Scharnhorst* and *Gneisenau* were fitted quite early with the latest German radar (Seetakt) and that in November 1939 this enabled them to steam through Royal Naval patrol lines in daylight.[29] Jeffrey Ethell and Alfred Price in their *Target Berlin* confirm that the B-17 and B-24 pathfinders of 482nd Bomb Group were fitted with the British H2S or its American derivative H2X, radar, enabling them to bomb through cloud.[30] Adolf Galland in his *The First and Last* provides a first hand account of the Channel Dash, thus giving an indication of the thoroughness of the German preparations

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[25] Basil Collier, *The Defence of the United Kingdom* (HMSO, 1957).

[26] Aileen Clayton, *The Enemy is Listening* (Crecy Books Limited, 1993).

[27] Alan W. Cooper, *Bombers Over Berlin* (Patrick Stephens, 1989).

[28] Michael Cumming, *Beam Bombers* (Sutton Publishing, Stroud , 1998).

[29] Len Deighton, *Blitzkrieg* (Grafton Books, 1990).

[30] Jeffrey Ethel and Alfred Price, *Target Berlin* (Book Club Associates, 1981).

for the transit.[31] Derek Howse in his *Radar at Sea* mentions the remarkable fact that a large convoy of merchant ships sailed through the Dover Straits at 5pm on D-Day in broad daylight, the first convoy to do so for four years.[32] David Irving provided much useful material about the German V1 and V2 in his *The Mare's Nest.*[33] Derek E. Johnson in his *East Anglia at War 1939-1945* gave helpful background information on the German raid on Norwich, when No 80 Wing engaged the attacking aircraft with radio countermeasures.[34] Life and work at RAF Defford, the airfield allocated to TRE, was well described by Albert Shorrock in *Pioneers of Radar* by Colin Latham and Anne Stobbs.[35] The same authors in *Radar: A War Time Miracle,* provided an explanation as to how Gee worked and gave an example of how Gee-H was used on D-Day by No 218 Squadron when Window was required to simulate an invasion fleet.[36] The secrets of the *Bruneval Raid* were disclosed in George Millar's account of the British raid on a German radar station; parts of the German radar were subsequently brought back to England for investigation by RAE at Farnborough.[37] In his *Why The Allies*

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[31] Adolf Galland, *The First and Last* (Methuen and Company, 1970).

[32] Derk Howse, *Radar at Sea* (Macmillan, 1993).

[33] David Irving, *The Mare's Nest* (William Kimber and Company Limited, 1964).

[34] Derek E. Johnson, *East Anglia at War* (Jarrold, Norwich, 1994).

[35] Colin Latham and Anne Stobbs, *Pioneers of Radar* (Sutton Publishing, Stroud, 1999).

[36] Colin Latham and Anne Stobbs, *Radar* (Alan Sutton, Stroud, 1996).

[37] George Millar, *The Bruneval Raid* (The Bodley Head, 1974).

Won Richard Overy pays tribute to Joseph Kammhuber's organisation of German air defence, mentions the devastating effect of Window and other countermeasure devices and also describes the advent of the new long-range allied fighter, the North American Mustang fitted with a Rolls-Royce engine.[38] Simon W. Parry presents an interesting picture of Operation Gisela and of German aircraft appearing over the United Kingdom on the night 3-4 March 1945.[39] Murray Peden, a Canadian, provides a fascinating account of life as a pilot on No 214 Squadron, engaged on countermeasure duties.[40] *In the Design and Development of Weapons,* M.M. Postan, D. Hay and J.D. Scott, explain the Doctrine of Quality and how it had to be dispensed with during the period of expansion and rearmament in 1934 and 1935; they then go on to explain the development of radar in the United Kingdom.[41] Germany's pioneering achievements, 1904-1945, are set out in *The Radar War,* by David Pritchard; the high technical standard of the equipment and the low standard of German radar operators is neatly brought out.[42] Henry Probert in his *Bomber Harris His Life and Times*, mentions the valid point, made by Albert Speer, that the

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[38] Richard Overy, *Why the Allies Won* (W.W. Norton and Company, New York, 1997).

[39] Simon W. Parry, *Intruders Over Britain* (Air Research Publications, Surbiton, 1987).

[40] Murray Peden, *A Thousand Shall Fall* (Imperial War Museum, 1981).

[41] M.M. Postan, D. Hay, .D. Scott, *Design and Development of Weapons* (HMSO, 1964).

[42] David Pritchard, *The Radar War: Germany's Pioneering Achievements 1904-1945* (Patrick Stephens Ltd, Wellingborough, 1989).

real importance of the air war consisted in the fact that it opened a second front long before the actual invasion of Europe occurred in June 1944.[43] *The Night Blitz 1940*-1941, by John Ray, interestingly goes over the reasons why the Luftwaffe was forced to turn to night bombing towards the end of 1940, at the end of the Battle of Britain.[44] Michael Renaut's *Terror by Night* is written by a former 100 Group Squadron Commander and provides much information about raising a radio countermeasure unit; he also disclosed that he owed his life to taking a scratch crew on operations, instead of his regular and more experienced one.[45] Frank Rowlinson explains in his *Contributions to Victory* how Metropolitan Vickers Electrical Company was able to introduce new design shops and thus help to design and make radio countermeasure equipment for the first time.[46] Bob Ruegg and Arnold Hague in Convoys *to Russia 1941-1945,* were able to assess the strength and pinpoint the location of the German Air Force units based in North Norway, quite accurately, and estimate the dangers to Allied convoys from such a force.[47] *Station X* by Michael Smith tells the story of the Codebreakers of Bletchley Park; it draws attention to the

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[43] Henry Probart, *Bomber Harris: His Life and Times* (Greenhill Books, 2001).

[44] John Ray, *The Night Blitz 1940-1941* (Arms and Armour Press, 1996).

[45] Michael Renaut, *Terror by Night* (William Kimber and Company Limited, 1982).

[46] Frank Rowlinson, *Contributions to Victory* (Metropolitan Vickers Electrical Company Limited, Manchester, 1947).

[47] Bob Ruegg and Arnold Hague, *Convoys to Russia 1941-1945* (World Ship Society, Kendal, 1992).

important connection between Station X and the RAF Y-Service units, Kingsdown and Cheadle.[48] In *Enemy below!,* Ted Sweet gives an excellent account of the Meaconing activities at Mundesley, in Norfolk, which was also the location of a Bomber Command and US Army Air Force Splasher Station.[49] B.L. Villa in *Unauthorised Action* describes the poor planning of the Dieppe raid, when the RAF lost 106 aircraft and mentions the fact that Mountbatten borrowed a number of Gee navigation devices from Sir Arthur Harris at Bomber Command for use by the ships taking part in the raid.[50] In *GCHQ, The Secret Wireless War 1900-86,* Nigel West explores the world of the RAF SIGINT Organisation, No 80 (Signals) Wing, RAF Countermeasure transmitters and the Enigma Intercept Stations.[51] In *Attack Warning Red* Derek Wood provides a history of air defence of the British Isles, bringing in the Observer Corps and the 1939 Air exercise, when radar tracks were married with visual sightings from the ground for the first time; he goes on to emphasise the importance of an integrated air defence system.[52] He also, in his *The Narrow Margin,* provides a clear account of the Battle of

[48] Michael Smith, *Station X* (MacMillan Publishers Ltd, 1998).

[49] Ted Sweet, *Enemy below!* (Square One Publications, Worcester, 1991).

[50] B.L. Villa, *Unauthorised Action: Mountbatten and the Dieppe Raid* (OUP, Ontario, 1989); Werner Rahn, ‘The War at Sea in the Atlantic and in the Arctic Ocean’ in Research Institute for Military History, Potsdam, Germany (eds.) *Germany and the Second World War: Vol. VI, The Global War*, p. 441

[51] Nigel West, *GCHQ: The Secret Wireless War* (Weidenfeld and Nicolson, 1984).

[52] Derek Wood, *Attack Warning Red* (Macdonald and Jane's, 1976).

Britain and includes the latest and most authoritative list of Luftwaffe losses published so far. He goes on to relate the development of radar for the German Navy 1934-35 and for the other German services shortly thereafter. He goes on to mention the German beams and the formation of No 80 (Signals) Wing.[53] The BBC Video, *The Secret War,* discusses the battle of the beams and introduces such personalities as Dr R.V. Jones, T.L. Eckersley of the Marconi Company, who was the country's leading expert in radio propagation, and E.A.B. Addison. In the video R.V. Jones makes the point that twenty-one factories were destroyed at Coventry and if the Luftwaffe bombing beams had not been overcome, the Rolls-Royce aerofactory at Derby and others were likely to have gone the same way with consequent disastrous results for Britain.[54]

Much has been written and published about radio countermeasures, but in order to understand the radio war fully, it is necessary to be aware of the contribution made by each of the key components. Thus it is essential to learn of No 80 (Signals) Wing and how and why it was created; how the Y-Service was able to provide this formation with the necessary intelligence, essential to its operations. How the success of No 80 Wing's operations led to the formation of No 100 Group, in order to control all radio countermeasures, ground as well as

[53] Derek Wood, *The Narrow Margin* (Tri-Service Press Limited, 1990).

[54] BBC Video, *The Secret War* (BBC Enterprises Limited, 1994), 2 vols., 1 BBC V5339.

air, and above all, how the Telecommunications Research Establishment came to provide the new and original hardware with which to fight the campaign, together with the necessary policies on how best to use it. This thesis therefore goes beyond what is already known.

3. Thesis Lay-out

In order to set the scene for the thesis, the first chapter recalls how practical wireless first came to Britain in 1896, in the hands of Marconi, and how his apparatus came to be accepted by the Royal Navy. It is also important to stress that wireless was an open method of communicating and hence it was considered necessary to use codes and cyphers: moreover, wireless was also subject to intentional interference or jamming, it was noted as early as 1914.[55] The chapter goes on to relate how great advances were made during World War One in the techniques of decryption and especially Direction Finding and, how at the end of hostilities, the Government Code and Cypher School was created. A brief description then follows of the struggle to maintain the Royal Air Force as a separate service between the years 1919-1933; as it ended, Hitler arrived on the scene in Germany: shortly the early models of Enigma, the commercial models of which were already in use, began to be issued to the German armed forces. The beginnings of radar in the United Kingdom are then explored and the importance of an

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[55] Nigel West, *GCHQ*, p.18.

integrated air defence system emphasised. The chapter goes on to stress how much the Royal Air Force came to rely on the Telecommunications Research Establishment.

Chapter Two opens by describing the training of Luftwaffe aircrews in the use of X-Gerät, before the commencement of hostilities in 1939 and of Knickebein and X-Gerät after that date. Enigma disclosed the existence of Knickebein to the British in May and June 1940 and how later in June the beams were found laid over the United Kingdom. In July it was confirmed that the Germans were using Medium Frequency radio beacons for navigation purposes while over the United Kingdom. RAF Meacons, transmitters designed to re-radiate the enemy beacon signals, were then introduced to combat the German beacons with great success. No 80 (Signals) Wing was formed to control all the measures being taken against the beams and beacons. It then became apparent that British countermeasures would have to be monitored for their effectiveness. This task was largely given to the aircraft of the Wireless Investigation and Development Unit. Further Luftwaffe navigation aids were uncovered such as Elektra. The Germans then took steps to avoid RAF Meaconing; and the Chapter ends with the uncovering of the third Luftwaffe beam, Benito, together with an account of the activities of Colonel Turner's Starfish department of the Air Ministry.

Chapter Three is concerned with the organisation and operations of No 80 (Signals) Wing in detail. It points out the advantages of establishing a good liaison with Fighter Command; and introduces the work of the Radio Countermeasures Board, which approved national policy and was the final arbiter whenever disputes arose between users of countermeasures. The Chapter ends by investigating some of the early measures taken by No 80 Wing.

Chapter Four discloses how Seetakt, the German coastal radar, came to be identified and how this event led to the uncovering of the early warning radar Freya. Further information about Wurzburg, the accurate height-finding radar, was then obtained by radio investigative flights that took place over France. More and more, the Germans were now seeking to avoid British countermeasures and their tactics are explained, along with the RAF attempts to bomb the German transmitters sited on the Cherbourg peninsula. The third German beam, Y-Verfahren, meanwhile remained under investigation by the Research Establishments, and it was during February 1941, that the first RAF countermeasure, Domino, was produced for Y-Verfahren. The X-Verfahren or Ruffians were used less in June 1941, although the system continued to be employed until withdrawn in the following July. Further information about the work undertaken by No 109 Squadron (formerly WIDU) is then provided. The detailed working of Benito now became available, resulting in the evolution of the second Benito jammer, Benjamin. The remainder of the Chapter provides an account of the rundown of the Luftwaffe in the west; the expansion of RAF jamming capability; and a late flurry of beacon and Meacon activity.

Chapter Five deals with the escape of the German Battle Cruisers *Scharnhorst* and *Gneisenau* through the English Channel, when British radar was jammed for the first time. It goes on to list the first RAF airborne devices, Moonshine and Mandrel, and how they were employed. The Chapter continues with the German Baedeker Raids on the United Kingdom and the raid on Norwich together with No 80 Wing's reactions. No 80 Wing's short excursion to northern Russia is then revealed; and the Chapter ends with reference to the newly introduced controls for German night fighters and the work being undertaken by TRE at Swanage and Malvern.

Chapter Six covers the low level of Luftwaffe activity over the United Kingdom during the latter half of 1942; this became more active in 1943, when German fight-bomber attacks started. The Germans then found a new use for Knickebein, and this was accompanied by a worrying increase in the number of Benito stations, which forced No 80 Wing to redistribute its transmitters. Night attacks then resumed against the United Kingdom; No 80 Wing responded successfully by using the jammer, Cigarette.

Bomber Command's failure to find its targets and bomb them accurately is brought out in Chapter Seven; it goes on to show how these shortcomings were overcome. A new commander was able to introduce techniques with the radio aids developed by TRE and so help to secure the future of the Command. Germany's improved air defences under the guidance of General Kammhuber then come under scrutiny; these improvements led to rising losses, forcing Bomber Command to adopt radio countermeasures for protection purposes. One of the measures used was Window; it was so successful that it caused a revision to the whole German night fighter system. It was important for Bomber Command to possess up-to-date and detailed knowledge of the latest German defences and here No 101 Squadron, with an electronic monitoring role, was of assistance. No 80 Wing, too, continued to play a part in the struggle. A series of British attacks against Berlin started in November 1943 and, as the loss-rate continued to rise, it was decided to form a new formation to bring together the application of manifold countermeasures under one authority. This was No 100 (Bomber Support) Group.

Chapter Eight continues with RAF attacks on Berlin and goes on to explain how, prior to the invasion of France, it was necessary for Bomber Command to attempt to hit small targets accurately by night. This it did successfully, somewhat to its surprise. As the RAF Berlin campaign drew to a close, the USAAF started to assault the German aircraft industry. The somewhat laborious task of creating an entirely new Group, in the middle of a war, is then covered together with the work of a small but significant unit of the USAAF. The Chapter ends with an investigation into TRE's contribution to the RCM Plan for Operation Overlord, the Plan being made by possible by the massive air superiority now available to the RAF and United States Army Air Forces.

After the successful landings in France, in June 1944, the strategic air force concentrated on supporting the allied land force, but with capacity to spare the German oil industry was also attacked. The German flying bomb and rocket attacks then started, when No 100 Group's ground and air jammers were able to make a contribution. The remainder of the Chapter is taken up with a description of the continuing Bomber Command attacks on German targets and the level of sophistication of the feints, ruses and diversions necessary in order to keep main force aircraft losses to a minimal level.

The Royal Air Force countermeasure organisation was formed at a perilous time for the United Kingdom in 1940. It was facing invasion daily with an army at home that had recently been ejected from the Continent, and largely bereft of its heavy weapons and equipment. Only the RAF was available to stand up to the Luftwaffe and so guarantee the safety of the British way of life. It was at this juncture that the Luftwaffe beacons and beams were found, dealt with and eventually mastered. This was not an easy undertaking. Firstly an organisation had to be improvised, equipment found and communications established, tasks not easy in the middle of a war, and which were to take time. The Research Establishments had to be approached and inducted into the requirements of No 80 Wing. Fortunately TRE was available, willing to assist and well-versed in RAF ways and procedures. However, all of this would not have been enough without intelligence, some of it high level, only obtainable from Ultra; the remainder fortunately could be acquired from RAF and national sources. By February 1942, as the defensive phase gave way to a more offensive spirit, German radar was jammed. And so began a period when first one side, then the other gained ascendancy in the radio war. It soon became obvious that as Bomber Command started to employ more and more electronic aids and countermeasures, another RAF controlling formation would be required. Hence towards the end of 1943, No 100 (Bomber Support) Group was formed and charged with the responsibility of providing all radio countermeasures to the RAF. Fortunately, when it was time to return to Europe in June 1944, the allies had established air superiority, and although radio countermeasures on the day were used to blind some German radars, they were largely employed on protecting allied aircraft and implementing successfully a number of deception plans. From this time onwards to the end of the war, countermeasures were employed almost exclusively on the protection of RAF and United States Army Air Force bomber aircraft, and notably in covering the D-Day landings.

CHAPTER ONE: WIRELESS, SIGNALS INTELLIGENCE, GOVERNMENT CODE AND CYPHER SCHOOL AND THE FORMATION OF, AND FIGHT FOR, THE ROYAL AIR FORCE

1. Marconi and the Beginnings of Signals Intelligence

During the Nineteenth Century, the Admiralty had long wished to be able to communicate with HM ships at sea quickly and accurately, especially with those out of sight of land. Great interest was thus taken in Marconi and his new development, wireless, when he arrived in Britain in 1896.[1] During the next few years he attempted to improve the performance of his equipment, while conducting a series of major demonstrations in order to convince the interested and indifferent alike of the advantages of using wireless as a means of conveying and receiving information. Representatives of the Admiralty were present at a trial held in 1899 when for the first time signals in morse code were passed by wireless from England to France over a distance of 32 miles. The Royal Navy was impressed, as were members of the public. The military authorities however, remained lukewarm, much preferring to continue to use telephone lines and telegraph. Shortly, transmitters and receivers were installed in two of HM ships, which were able to communicate successfully with one another while at sea and some 85 miles apart. A year later, and after a further increase in range, the Admiralty placed a contract with Marconi for exclusive rights to his equipment.[2] Notwithstanding the legal niceties of this arrangement, the Army then proceeded to construct

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[1] Frances Donaldson, *The Marconi Scandal* (Rupert Hart-Davis, 1962) p.11; Nigel West, *GCHQ: The Secret Wireless War*, pp.6-7.

[2] Nigel West, *GCHQ: The Secret Wireless War*, pp.10-12.

its own Marconi field wireless station. The subsequent trial, however, held in South Africa during the Boer War, was unsuccessful and the equipment was handed over to the Royal Navy, who gratefully and promptly made full use of it. In due course, and to facilitate communication with the fleet, the Admiralty placed an order with the Marconi Company for a number of shore stations to be erected in England and Ireland and, at the same time, it decided to equip some twenty-six warships with wireless apparatus. While work proceeded with these contracts, wireless signals were sent across the Atlantic from the Marconi transmitter situated at Poldhu, in Cornwall and successfully received in Newfoundland. Once the fleet was fitted with wireless the Admiralty would be able to keep in touch with its ships at sea for the first time.[3]

In the United Kingdom it was already understood that wireless telegraphy was an open, and thus insecure, means of communication. Indeed, Professor Oliver Lodge had confirmed this point to the General Post Office (GPO) in 1903.[4] The army too, had realised that anyone with an appropriate receiver could listen to such transmissions without much difficulty. Moreover, censorship experience gained during the Boer War had taught the authorities the advantages of controlling such emissions. In spite of the efforts of a small number of wireless enthusiasts in the army, however, the army in general continued to rely on cable and telegraph for most of its communications.[5] The Committee of Imperial Defence (CID), formed after the Boer War to provide the government of the

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[3] Ibid.

[4] Ibid.

[5] Ibid., p.12.

day with the best available high level defence advice, took another view. Lord Haldane, the Secretary of State for War from 1905 to 1912, shortly authorised the creation of a War Book containing essential measures to be taken in the event of a major crisis or war.

From this relatively simple but far-sighted and vital measure sprang the idea of a formal Secret Service (MI5) and the drawing-up, in advance, of a list of names of persons thought to be suitably qualified for employment in intelligence and cypher duties. The War Office attitude at the time discouraged the learning of foreign languages. Eventually the commercial world was approached for individuals who could speak foreign languages and who might be employed on intelligence work. Several influential firms, and others, responded and these included shipping lines, a major bank and a telegraph company. In 1906 the army started to think again about employing wireless as a major means of communication. It was therefore somewhat fortunate that relevant trials and experiments had been allowed to continue at centres such as Aldershot and Chatham. At long last a new signal service was formed and a Director of Telegraphs and Signalling approved. It took the Army until 1913 before these changes were fully implemented and Telegraph gave way to Signals, even so, the cavalry was the only arm in the British Expeditionary Force (BEF) equipped with wireless, until 1917. They made full use of it.

In 1909 Marconi was awarded the Nobel Prize for physics, but this did not help him very much in the commercial sense. Progress was slow and in the following year, exasperated by the delays and political in-fighting occurring in London, his company proposed a plan to link the Empire by wireless. His proposals using eighteen high power stations were given further impetus by the knowledge that Germany was embarking on a similar scheme to connect its own colonies with Berlin.[6] France too, had similar aspirations and wished to establish communications between Paris and North Africa. The CID was strongly in favour of an Empire wireless chain and recommended such a link to the government. Because of strong opposition to the Marconi Company, stemming from an alleged stock exchange scandal, some ministers had bought shares in the American Company, and it took until August 1913 before the House of Commons approved final contracts for six wireless stations, which would form a chain connecting Britain with Australia. Marconi did not get his eighteen stations, but six were better than none at all, or so he thought at the time. In the event, the Marconi Company did not complete any of the six and when the contract was cancelled, somewhat abruptly, it was awarded £600,000 by way of compensation. Such was the antipathy, however, displayed towards the Marconi Company because of the share scandal, although not towards Marconi himself, that the Empire had to wait until the autumn of 1927 for the installation of a complete system of wireless communication.[7]

Naval intelligence then produced, at a subsequent sub-committee meeting of the Committee of Imperial Defence, a world-wide survey of British and foreign wireless stations in considerable detail. This gave the CID the advantage of deciding, in advance, which communications should be disrupted, intercepted or left alone in time of war. At a second meeting of this important sub-committee on 29 June 1914 the subject of intentional interference or jamming was raised. Mr Wilkins the Treasury

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[6] Viscount Samuel, *Memoirs* (The Cressey Press, 1945), pp.74-77.

[7] Frances Donaldson, *The Marconi Scandal*, p.243.

representative, ever mindful of the public purse, said:

> it was for consideration how far it was worth expending money on apparatus [i.e. wireless] that might be rendered useless in wartime.[8]

In accordance with secret clauses contained in the War Book, censorship of communications was imposed in August 1914. But postal censorship had been overlooked and thus an appropriate organisation had to be hurriedly introduced to discharge this particular task.

Once trench warfare commenced in France in 1914, the British Army found its beloved telegraph wires were soon destroyed by German artillery fire. To stand any chance at all of passing information to and from forward units, cables had to be buried several feet underground and pigeons utilised as message carriers on a massive scale.[9] The few wireless sets that were available had been allocated to the cavalry and these were used to good effect. German transmissions were overheard with the aid of this equipment and the intercepts passed to GHQ where they were successfully analysed. Soon the British Army became proficient at traffic analysis and, with the help of its newly developed technique of Direction-Finding (DF), was able to identify many German military units and formations and plot their positions and subsequent movements. Needless to say the War Office was delighted with this turn of events.[10] Moreover, with the help of

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[8] Nigel West, *GCHQ*, pp.18-19.

[9] Ibid., pp.28-29.

[10] Ibid., p.30.

specialised wireless equipment German telephone conversations were overheard. For similar reasons British conversations had to be banned within 3,000 yards of the front line. This then was the start of modern Signals Intelligence, or SIGINT, which not only included interception of wireless signals but de-cryption of the messages as well as a detailed analysis of the traffic itself. The potential usefulness of SIGINT was not lost on the War Office, which was then in the process of being reorganised by Kitchener. A Director of Military Intelligence was re-introduced, and the BEF, given its first Director, started to develop its own intelligence organisation. Throughout the winter of 1916 the BEF took advantage of the Germans' increased use of landlines by enlarging and improving its SIGINT capability. A special unit analysed the information obtained and recommended appropriate action. In London, the War Office established units to study such intercepts, to develop traffic analysis and to improve methods of decryption.[11]

Meanwhile, the Admiralty had made much progress with the interception and de-cryption of German naval wireless signals. They had created their own large and effective intelligence organisation, which, with the aid of an efficient Direction Finding service, was able at times to keep track of units of the German surface fleet and U-boats and Zeppelins. Jamming of German naval signals was also undertaken and some success achieved. Thus allied ships and convoys could be routed around German U-boat or surface ship locations, if these were known in advance. Then, if it was both advantageous and possible to do so, an attempt could be made to intercept and attack the German units. In this way eight Zeppelins were destroyed in 1916 alone. Above all, perhaps, it was

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[11] Ibid., p.32.

the Admiralty's superb team of code-breakers in Room 40, which enabled the allies to read much of Germany's wireless traffic.[12]

After the end of the war in 1918 the United Kingdom started to disarm as quickly as possible. Careful plans had been drawn up to prevent too many men being released too quickly thus causing unemployment but, due to public clamour, these were abandoned in favour of the principle of 'first in — first out'. Consequently, within a year over four million men were demobilised. As the demobilisation machinery gathered momentum, it became evident that vital intelligence services and techniques could be lost in the process. Consequently the War Cabinet, in 1919, decided to create a Secret Service Committee to review existing arrangements. From this came the important and far-reaching decision to establish a Government Code and Cypher School (GC and CS — now GCHQ), which came into existence on 1 November, 1919.[13] The following year a clause was inserted into the Official Secrets Act requiring all cable companies operating from British territory to submit copies of traffic, transmitted and received, to the government within ten days.[14] The tasks being passed to the Government Code and Cipher School (GC & CS) were to study the ciphers used by other governments and to advise on the security of national codes and cyphers. From experience already gained, especially during World War One, wireless traffic had proved to be a valuable source of intelligence. Hence the origin of Signals Intelligence (SIGINT),

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[12] John Terraine, 'The Substance of War', in Hugh Cecil, and Peter H. Liddle, (eds.) *Facing Armageddon, The First World War Experienced*, (Leo Cooper, 1996), pp.6-7; Nigel West, *GCHQ*, pp.36-38.

[13] F.H. Hinsley, *British Intelligence in the Second World War,* vol.1, p.20.

[14] Nigel West, *GCHQ*, p.75.

which involves the study of communications systems, and interception of such communications. Personnel for the new organisation were recruited from staff formerly employed in Room 40 of the Admiralty and MI 1(b) of the War Office, the cost being borne by the Foreign Office.

The War Office then decided to reorganise its SIGINT arrangements and in August of 1920 formed the Royal Corps of Signals. A military wireless communications chain was maintained, with the overseas garrisons and intercepts acquired by elements of the chain, or the garrisons themselves, being passed to GC and CS for decryption and appropriate action. As a result of these arrangements the Cabinet was furnished, inter alia, with information disclosing Soviet involvement in the internal and external affairs of the United Kingdom, including a subsidy paid to the *Daily Herald* newspaper.[15] In 1923 it was decided that the head of the Secret Intelligence Service should become, in addition, Director GC and CS. Although foreign cypher traffic was declining at the time, the three armed services agreed with these changes, albeit with some reservations. Nevertheless, a Naval Section was added to GC & CS from 1924, an Army section from 1930 and, very belatedly, the Air Section from 1936.[16] Since its inception the Army team had become involved with German air matters. This parasitical arrangement suited the RAF as it saved manpower, but with the surge in Luftwaffe traffic from 1935 onwards, the Army

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[15] Ibid., pp.76-77.

[16] In the army and RAF, intelligence was then subordinated to operations, moreover RAF intelligence was not highly regarded in the 1920s and 1930s. Donald Cameron Watt, ‘British Intelligence and the Coming of the Second World War in Europe’, in Ernest R. May, (ed.), *Knowing One's Enemies* (Princeton, Princeton University Press, New Jersey, 1984), p.242, pp.256-260.

increasingly found it difficult to continue with the task, hence the RAF presence from 1936.[17] At the time all the service personnel involved were employed on cryptanalytical work only. To provide the necessary guidance and to establish priorities, GC & CS established a Cryptography and Interception Committee in 1924; but, since this met infrequently, a standing sub-committee had to be formed four years later to co-ordinate all wireless interception. This was the important Y Sub-Committee. The three services were represented on both bodies and they retained control of the personnel involved and their own interception stations. But they could not have the latter everywhere: thus by the 1930s a system had developed whereby the War Office concentrated, mainly but not exclusively, on the Middle East, the Royal Navy on the Far East, and the Royal Air Force, with its limited facilities, on the United Kingdom. Even so, the War Office maintained a SIGINT station at Devizes in the UK and the Home Office a station at 113, Grove Park, Camberwell that concentrated on Soviet diplomatic traffic.

2. The Royal Air Force 1919-1933

The year 1919 for the RAF was to mark the beginning, not the end, of a struggle to maintain its existence as a separate and equal armed service of the crown. The very man who helped bring the RAF into existence, Lloyd George, raised the first hurdle to the continuation of a third service. Re-elected in the 'Coupon Election' of December 1918, the Prime Minister of the new government made Churchill Secretary of State for War and Air, fully intending on the grounds of economy, to dispense with the Air Ministry as a

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[17] Public Record Office (PRO) Government Code Headquarters HW 43/1, p.3.

separate department, as soon as he could conveniently do so. Lloyd George then busied himself with the Peace Conference held in Paris from January 1919. Later he was to change his mind about disbanding the RAF, without any prejudice, however, towards reducing government expenditure on defence. Thus for the moment the RAF could expect to continue to exist as a separate service but would still be subject to any necessary financial retrenchment. Meanwhile, the first Chief of Air Staff, Hugh Trenchard, had resigned his position over differences with Lord Rothermere, the then Air Minister, but in the following year he had been persuaded by Churchill to resume his former post.[18] He returned to the Air Ministry on 15 February 1919.[19] He was going to need all his faculties and powers of reasoning, if the infant RAF was to grow and be accepted as an equal with the Royal Navy and Army.[20]

Trenchard was determined that the air force should continue as a separate entity, no matter what its size, be administered as economically as possible and, above all, be capable of rapid expansion should the need ever arise. By 1920 the post-war boom had turned into a slump and a year later into a depression. By this time Lloyd George had introduced his 'Ten Years Rule', which assumed that no major conflict would arise for the next ten years. Conveniently, the rule was renewed annually and certainly had its desired effect of tightening the Treasury grip on service expenditure. Unfortunately for Trenchard this debilitating rule was

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[18] C. Webster and N. Frankland, *The Strategic Air Offensive Against Germany*, 4 vols. (HMSO, 1961), vol.1, pp.38-39.

[19] Andrew Boyle, *Trenchard* (Collins, 1962), p.332.

[20] Ibid., pp.343-344.

not rescinded until 1932.[21] By then the years of minimal expenditure on defence had adversely affected not only the state of efficiency of all three services but also the nation's aircraft industry. During a time of great financial stringency, therefore, Trenchard not only had to convince the government of the day of the necessity of maintaining a separate air force in peacetime, but he also had to persuade the chiefs of the other services as well, perhaps a harder task.

3. Hitler and Enigma

Germany had experimented with cryptographic devices in the closing months of World War One, but little was heard of them until 1926, when the German Navy began to be supplied with a sophisticated military version of a machine called Enigma, the Scherbius or civilian model of which was already in commercial use.[22] By the end of 1935 some 20,000 of these machines were available for use by the three German services.[23] Germany continued to improve Enigma to such an extent that by the outbreak of World War Two it considered the cypher safe from decryption. Meanwhile, the Polish Cypher Bureau had become interested in deciphering Enigma traffic as early as 1928, and had acquired one of the commercial Scherbius machines.[24] Subsequently, in 1931, the French acquired Enigma settings and passed them for the first time to the Poles. A strong team of mathematicians was employed on this complex task and resulted

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[21] Denis Richards, *Royal Air Force 1939-1945*, 3 vols. (HMSO, 1953), vol.1, p.18.

[22] F.H. Hinsley, *British Intelligence in the Second World War*, vol.1, p.487.

[23] Ronald Lewin, *Ultra Goes to War* (Hutchinson and Company, 1978), p.45.

[24] Ibid.

in the Polish cypher teams starting to read Enigma messages. The German Navy, however, decided to alter its Enigma in 1937 and consequently the Polish teams were unable to continue to read the navy traffic. The following year the indicating system used by the German Army was altered, bringing Polish success with this particular system to a halt.

In 1933 Adolf Hitler became Chancellor of Germany and started to put in train a succession of events that ultimately would lead to the opening of hostilities between that country and the United Kingdom some six years later. As knowledge of the expanding German armed forces, especially the German Air Force, became known in London, disarmament gave way to re-armament and it was at the beginning of this period that the Director of Air Intelligence decided, in 1934, to increase the service's interception capability and created a small wireless monitoring station at RAF Waddington in Lincolnshire.[25] Such was the influx of general traffic intercepted, however, that a new department, AI 1(e), had to be established in the Air Ministry in order to analyse it all.

In contravention of the terms contained in the Treaty of Versailles, Hitler signed a decree in February 1935, formally creating the Luftwaffe on the first of the following month.[26] But the German Air Force had already been formed and its existence had been known for some time; indeed it had been considered to be a potential menace to the United Kingdom the year before.[27] Much

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[25] Nigel West, *GCHQ*, p.110.

[26] David Irving, *The Rise and Fall of the Luftwaffe*, pp.44-46; Air Vice Marshal Tony Mason, *Air Power: A Centennial Appraisal*, p.47.

[27] C. Webster and N. Frankland, *The Strategic Air Offensive Against Germany, 1939-1945*, vol.1, p.67.

low-grade wireless traffic started to be intercepted regularly from 1934 onwards and this helped in estimating the size and dispositions of the German Air Force. Indeed, by this means some sixty ground stations were identified along with 578 aircraft by September of that year. High-grade information, however, enciphered with the aid of the electro-magnetic Enigma machine, remained unreadable, although some success was obtained at GC and CS in 1937 when several of the older and less secure machines were used during the Spanish civil war. Flowerdown and Fort Bridgewoods, near Chatham, were the two intercept stations involved.[28] Even so, this limited success only seemed to confirm that traffic encrypted with the aid of the newer versions of Enigma, at the time only deployed inside the Reich, would be impenetrable, provided the operators used the relevant procedures correctly.

To help find appropriate Enigma keys, the Polish bureau started to develop a system of perforated sheets and introduced the world's first electro-mechanical cryptographic bombe.[29] To complicate matters further, in 1939, the German Army's Cypher office increased the number of Enigma plugboard sockets, thus rendering the bombe unreliable as the main cryptographic tool. Because of this situation, and following the British Cabinet's decision to support Poland, the Polish cryptographers, in July 1939, decided to inform France and Great Britain of their success with Enigma from 1933 to 1938, and that they could be successful again if the new and enlarged perforated sheets could be produced in quantity. Indeed, they actually built a number of Enigma

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[28] Nigel West, *GCHQ*, p.110.

[29] F.H. Hinsley, *British Intelligence in the Second World War,* vol.1, p.492.

machines and presented one each to France and Great Britain.[30] A few days after Poland was invaded in September 1939, their cryptographic team hurriedly moved to France where they waited for the perforated sheets to arrive from the United Kingdom to enable them to continue their work.

Meanwhile, the United Kingdom Government had decided that Enigma, suitably modified by an additional British attachment, known as Type-X, should be made available to the Royal Air Force and the Army. If used correctly, this device made it impossible for any intercepts to be deciphered. On hearing this news, the head of GC & CS became so pessimistic that, in the event of a foreign power adopting such a combination, he considered his establishment would be rendered redundant. Nevertheless, the Y Committee arranged for further intercept stations to be constructed in order to be able to concentrate on German and Italian diplomatic traffic. The Austrian Anschluss in March, 1938, had a profound effect on the United Kingdom and France, not least on their respective intelligence communities. Moreover, the subsequent and disturbing events concerning the Sudetenland and Czechoslovakia persuaded the Treasury to agree to an expansion of GC & CS and thus, in 1939, very late in the day, a German section was established and many additional linguists acquired from the commercial world and universities. In addition, it was decided that Bletchley Park, in Buckinghamshire, should be used as an alternative to the London Broadway HQ.[31] The then chief of the Secret Intelligence Service, Admiral Sinclair, had purchased the estate at Bletchley in 1938 with some forethought. Intercept

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[30] Michael Smith, *Station X: The Codebreakers of Bletchley Park*, p.19.

[31] Gordon Welchman, *The Hut Six Story* (Allen Lane, 1982), p.9.

facilities, however, still remained somewhat slender as GC & CS went on to a war footing on 1 August 1939, the Air Ministry still depending on the small unit located at RAF Waddington. Fortunately, and in accordance with Y Committee policy, the Air Ministry had decided to prepare another site at Cheadle in Staffordshire, and this, signals unit No 61, was destined to be enlarged and become considerably more important as the war progressed. Indeed, it was to become the Royal Air Force's pre-eminent Y Wireless Telegraphy intercept station.[32]

4. Radar and the Integrated Air Defence of the UK

Meanwhile, the international situation was deteriorating rapidly. Moreover, there had been little significant improvement in the United Kingdom's air defence arrangements since the end of World War 1, although it is true that various plans had been drawn up, such as the Steel-Bartholomew plan of 1923, which attempted to integrate observer posts, anti-aircraft guns and fighter defence, but relied on early warning being provided by sound locators, the 52 Squadron Scheme, and, with the re-emergence of the German Air Force as a potential threat to London and other cities of the United Kingdom, the Reorientation Scheme of 1935.[33] Most of these, however, were all variations of ideas extant in 1918. Some improvements had been made with sound detection, and a few detectors had actually been constructed out of concrete by the Royal Engineers, for use by the Royal Air Force.[34] Subsequent trials with aircraft, however, had proved to be disappointing and

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[32] F.H. Hinsley, *British Intelligence in the Second World War,* vol.1, pp.14-15.

[33] John R Bushby, *Air Defence of Great Britain,* pp.79, 81-82, 84-85.

[34] Richard N. Scarth, *Mirrors by the Sea* (Hythe Civic Society, Hythe, Kent, 1995) plates 1-22.

tended to confirm current thinking that the bomber would always get through to its target.[35]

Interest in air defence then began to gather pace, especially within the Air Ministry itself. Action by the Air Ministry Director of Scientific Research, H.E. Wimperis, resulted in Lord Londonderry, the Secretary of State for Air from 9 November 1931, establishing a special committee under the chairmanship of Sir Henry Tizard, with Professors A.V. Hill and P.M.S. Blackett to help him. It met for the first time in January 1935 and was known as the Committee for the Scientific Survey of Air Defence. Meanwhile H.E. Wimperis, who had designed the first course-setting bombsight for the Royal Naval Air Service in 1917, enlisted the help of Watson Watt, the Director of the National Physical Laboratory.[36] The latter had been a meteorologist and subsequently had devoted much time to studying the detection and location of thunderstorms with the aid of radio waves and equipment that included a cathode ray tube. Watson Watt was therefore well aware of the reflective properties of radio waves.[37] With the help of his assistant, A.F. Wilkins, he advised Wimperis that it might be possible to detect aircraft by exploiting this phenomenon. From then on events moved swiftly. Further pertinent details were quickly furnished to Watson Watt who then submitted a remarkable document, which later came to be known as the 'Radar Charter'.[38] Members of the Committee studied the charter on 21 February and were so impressed with the author's grasp of the air defence problems, and the methods

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[35] Ibid., p.36.

[36] Neville Jones, *The Origins of Strategic Bombing* (William Kimber, 1973), pp.20-21.

[37] E.G. Bowen, *Radar Days*, p.7; John Bushby, *Air Defence of Great Britain*, pp.100-101.

[38] Ibid., p.102.

proposed to overcome the manifold difficulties facing them, that within a week the Secretary, A.P. Rowe, had not only informed the then Air Member for Research and Development of this timely and promising development, but gained his wholehearted support.[39] The very same day the well-known and much written-about trial was held near Daventry when a Heyford bomber reflected the short waves emanating from a nearby BBC transmitter, the outcome being clearly seen on a cathode-ray tube.[40]

Dowding was impressed with the results and set to work to obtain public money for further research. With the backing of the new Secretary of State for Air, Viscount Swinton, and the Air Council, a sum of £10,000 was found surprisingly quickly, together with a suitable research site, Orfordness, just 15 miles down the coast from Aldeburgh in Suffolk. Soon, thanks largely to the dedication of a small team of enthusiasts; the range of detection of known aircraft was pushed out to a distance of forty miles, then eighty and hundred miles.[41] Various tests and trials followed, leading to the problems connected with Direction-Finding being largely overcome.[42] By October 1935 the Research Station had outgrown its facilities and moved to Bawdsey Manor, some fifteen miles to the south, which offered better conditions for radar trials and more secure surroundings. Such was the progress made that shortly thereafter the Treasury agreed, as an interim measure, to the necessary expenditure for a chain of five stations to be

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[39] Air Chief Marshal Sir Hugh Dowding, quoted in Denis Richard's, *Royal Air Force 1939-1945,* 3 vols., vol.1, p.404.

[40] John Bushby, *Air Defence of Great Britain,* pp.104-105.

[41] E.G. Bowen, *Radar Days,* p.16.

[42] John Bushby, *Air Defence of Great Britain,* p.107.

established to cover the approaches to London.[43] Consequently contracts were placed, under great secrecy, with Metropolitan Vickers for transmitters in the 6-15 metre range and A.C. Cossor for the Receivers; the latter company being the largest manufacturer of Cathode Ray tubes in the United Kingdom.[44] Radar masts had now reached a height of over 200 feet and were to go higher, but, in spite of possible construction problems, it was still hoped that the new stations would be ready in time to participate in the air defence exercise scheduled for that summer. Due to delays in construction at the other sites, Bawdsey was the only station fully to take part. The subsequent results were disappointing, many aircraft not being detected or detected too late. The Chief of Air Staff, Sir Edward Ellington, was sufficiently far-seeing to decide that the project should, nonetheless, be continued.[45] It was to develop into the Chain Home (CH) and Chain Home Low (CHL) early warning systems used so successfully against German aircraft approaching the United Kingdom during World War Two, especially in daylight during the Battle of Britain.[46]

As developments continued to take place at Bawdsey, thought was given in the Air Ministry to deciding who was going to operate the air-warning network and what method of recruitment and training of the necessary personnel would be required. Operations rooms were going to have to be manned in order to assess and collate the acquired data and to operate the vital communications system, which would enable fighter aircraft to be scrambled and

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[43] Denis Richards, *Royal Air Force 1939-1945*, vol.1, pp.23-25.

[44] Reg Batt, *The Radar Army* (Robert Hale, 1991), p.16.

[45] John Busby, *Air Defence of Great Britain*, pp.109-110.

[46] M.M. Postan, D. Hay, J.D. Scott, *Design and Development of Weapons*, p.378.

subsequently guided to their respective targets. In 1936, Squadron Leader R.G. Hart was the officer selected for this new task; in order to be able to work closely with the scientists developing the radar network, he chose Bawdsey as his training centre.[47] While the pertinent reporting procedures were being worked out, it became apparent that it would be possible for two or more adjacent CH stations inadvertently to report the same aircraft. In order to avoid any confusion that might arise from such a situation, Hart introduced the Filter Room where raw radar data could be crosschecked and refined before being passed to Operations Rooms for display and information purposes.[48]

With many of the major and most pressing problems of the Chain Home (CH) system overcome, Tizard and Watson-Watt could think more about future developments and address the difficulties of installing radar equipment into the cockpits of night fighter and other aircraft. Construction of ground stations had been difficult enough even without having to take into consideration such factors as power requirements, weight and size. In the air these considerations of power, weight and size became paramount. Fortunately, Tizard and Watson-Watt had already given some thought to these problems and their views and ideas were passed to the staff at Orford and Bawdsey Research Stations. What was required was equipment small enough to be installed in a night fighter, which would enable a pilot on his own to close from a range of ten to fifteen miles down to about five miles.[49] Dr E.G. Bowen was eager and willing to head an airborne radar group, which, in

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[47] John Bushby, *Air Defence of Great Britain*, pp.115-116.

[48] Ibid.

[49] E.G. Bowen, *Radar Days*, pp.30-31.

the beginning, consisted of a staff of one. By the end of 1936 he had successfully constructed an airborne radar receiver small enough to be installed in a Handley Page Heyford aircraft from nearby RAF Martlesham Heath, then the home of the Aeroplane and Armament Experimental Establishment (AAEE).[50] The work was of critical importance and was eventually to lead to the first use of Air Interception (AI) and Air to Surface Vessel (ASV) radar equipment in aircraft. By the beginning of 1937, Dr E.G. Bowen had achieved outstanding results with his airborne radar transmitter and receiver, operating on a frequency of one-and-a-half metres, installed in an Avro Anson.[51] At this stage Great Britain was ahead of Germany in airborne radar, there simply being no requirement at that time for Air Interception equipment in a country with the most powerful air force in the world. The FuG Lichtenstein BC AI radar, which was subsequently developed and manufactured by Telefunken, entered service in 1942-43 and was developed from the 1939 Lichtenstein B high-altitude radio altimeter.[52]

Meanwhile, for the Royal Air Force, the whole concept of radar was new, and secret, and only those who needed to know were informed about its role in air defence and other uses. In 1936 Tizard suggested trials should be held to determine exactly how, and how accurately, a controller would be able to direct an intercepting fighter on to an enemy aircraft, using information obtained from radar sources. As a result the Royal Air Force subsequently held what came to be known as the 'Biggin Hill'

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[50] Tim Mason, *British Flight Testing* (Putnam, 1993), pp.42-43.

[51] E.G. Bowen, *Radar Days*, pp.41-42.

[52] Martin Streetly, *Confound and Destroy*, p.179.

experiment.[53] It was from these extremely important trials, and those that followed, that Fighter Command learned it could dispense with wasteful, and generally inefficient, standing patrols, requiring fighter aircraft to be constantly airborne, and instead to rely on timely and accurate information from the Chain Home network, augmented by information furnished by the Observer Corps. For the first time radar and ground tracks were compared.[54] In due course Controllers became proficient in the new technique of directing fighter aircraft with the aid of recently introduced radio telephony, and using filtered information displayed on a map situated in front of them in the operation centre. With practice, it became possible to estimate the course in degrees, which a fighter pilot should steer in order to effect a successful interception. From 1937 to the outbreak of hostilities with Germany, the RAF concentrated on improving air and ground radar, and in training the personnel who were to operate the radar system.

In February 1940, J. Randall and H. Boot devised the world's first magnetron at Birmingham University. This device produced a pulsed output of over one-Kilowatt at ten centimetres, unheard of figures at the time. Not only did the magnetron make it possible for the British to introduce centimetric radar, but it also led to a radical improvement in radar generally.[55] Quite early in 1940 Sir Henry Tizard suggested that British secrets should be disclosed to the USA in return for technical and production assistance. Both

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[53] Ibid., pp.117-119.

[54] Ibid.

[55] Reg Batt, *The Radar Army*, p.96; Air Vice Marshal R.A. Mason, *Air Power: An Overview of Roles*, pp.18-19.

governments agreed by late July to the visit by Tizard.[56] Consequently, towards the end of August 1940, Sir Henry led a Mission to Canada and the USA, in the course of which British secrets such as the jet engine, radar in its many forms and the unique resonant magnetron were disclosed.[57] Indeed, the hope was to invoke the technical and productive resources of the whole North American continent. In this way, over a million magnetrons of every type came to be made by US companies in the United Kingdom, or in the USA, which were subsequently incorporated in hundreds of thousands of allied radar sets, including those used by the Royal Air Force.

The Observer Corps was not a new organisation, having come into existence as a result of the knowledge and experience gained during the German air raids on London during World War One. It was to make a big contribution in World War Two. A Major General, E.B. Ashmore, had been made responsible for organising the air and ground defences and for extending the system beyond the Metropolitan area. The observer network comprised a number of posts linked by telephone to a control room. These were manned at first by troops, and later police, who used a common reporting code based on a gridded map. At the end of the war in 1918, Ashmore proposed the formation of a peacetime air-defence network composed of aircraft, guns, searchlights and observers enrolled as special constables, all placed under one commander. The Committee of Imperial Defence subsequently approved the

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[56] E.G. Bowen, *Radar Days,* pp.150-151.

[57] Colin Latham and Anne Stobbs, *Pioneers of Radar*, pp.4-5.

scheme and the corps was officially approved in October 1925.[58] Subsequent air exercises proved the indispensable value of the Observer Corps and brought closer links with the Royal Air Force, resulting in the appointment of Air Commodore E.A.D. Masterman RAF (Ret'd) as the first Commandant in 1929.[59] As radar was introduced and integrated into the air-defence arrangements from 1936 onwards, visual reporting of enemy and friendly aircraft, especially when flown at low level or overland, was given as much prominence as ever. King George VI was to award the prefix 'Royal' to the Observer Corps in 1941.[60]

5. Telecommunications Research Establishment (TRE) and the Start of Radio Countermeasures

It is noteworthy that up until the first half of 1936, personnel working at Bawdsey had been employed by the National Physical Laboratory; but on 1st August of that year, responsibility for the Bawdsey Research Station (BRS) passed to the Air Ministry, thus enabling Squadron Leader R.G. Hart to start his radar training courses at that location. Watson Watt moved up to the Air Ministry in 1938 to become Director of Communications Development (DCD), being replaced at Bawdsey by the former Secretary to the Tizard Committee, A.P. Rowe. In accordance with a plan devised by Watson Watt, BRS moved to Dundee University in Scotland in September, 1939, the airborne side going to Perth. A.P. Rowe was a capable, scientific civil servant; but moving there was an unwise decision, the accommodation being unsuitable, as it was

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[58] Directorate of Public Relations (RAF) *Chronology: 50th Anniversary of the Royal Air Force* (MOD, 1968), p.10.

[59] Derek Wood, *Attack Warning Red*, p.29.

[60] Directorate of Public Relations (RAF) *Chronology*, p.17.

at Perth. Taffy Bowen placed the blame for this state of affairs firmly on the shoulders of Watson Watt and A.P. Rowe.[61] In spite of the location, the organisation was still expanding and one of the several recruits at the time to the airborne division was a young Bernard Lovell. The title Bawdsey Research Station was obviously unsuitable for Dundee, and was changed accordingly to Air Ministry Research Establishment (AMRE). After two months the airborne side, complete with aircraft and forty odd personnel of D Flight AA&EE, moved to RAF St Athan. On the face of it, St Athan should have been ideal, being a large station and well away from the East and South coasts: but it was a busy technical training unit with limited resources. Since St Athan was an unsuitable place to conduct research, most of the work here involved fitting AI into Blenheims for Fighter Command, and ASV mainly into Hudsons of Coastal Command. However, in May 1940, while momentous events were taking place on the Continent, both components of AMRE were moved to yet another location, Swanage in Dorset, to a specially prepared, but ill-equipped site on the coast, vulnerable to German air attack and assault from the sea.[62]

However, AMRE now became the Telecommunications Research Centre (TRE), with D Flight, originally from Martlesham, being absorbed into TRE's airborne division, being based at Christchurch aerodrome. It was here at Worth Matravers, in August 1940, that a Radio Countermeasure Group (RCM) headed by Dr Robert Cockburn was created. The RCM Division was developed from this. At the time, most of TRE's research was directed towards protecting the United Kingdom, and its

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[61] E.G. Bowen, *Radar Days*, pp.84-87.

[62] Ibid., pp.137-138; PRO Avia 7/601; Pro Avia 7/602; Pro Avia 7/603.

manufacturing industry, from the attentions of the Luftwaffe. Much effort, therefore, had to be given to improvements and strengthening of the RAF's night fighter defences, especially in the further development of the first air interception radar (AI). In 1941, TRE proposed that some form of radio countermeasure might be used to support offensive air operations. The idea was a novel one; Bomber Command, the sole means of carrying the war to the German homeland at the time, rejected it out of hand, believing that their existing methods of navigation were adequate and that Radio silence had to be maintained at all costs, if the position of their aircraft was not to be disclosed to the Luftwaffe. Bomber Command was over-confident in its ability to deliver the bomber offensive. Fighter Command, however, had no such objections. On 22 June 1941, Germany attacked Russia and, in doing so, had to deploy much of the Luftwaffe away from the West in order to support its operations in the Mediterranean and the East. This in turn freed TRE to come to the assistance of Bomber Command which, because of rising casualties, poor navigation and bombing inaccuracy, was now more disposed towards the use of radio and radar aids. But TRE did not always enjoy the highest of priorities and it took the discerning Lord Cherwell to realise that, once Churchill had been persuaded to back priority development of scientific navigation and bombing aids, additional measures were necessary. This resulted in the appointment of Sir Robert Renwick who, in addition to his other responsibilities, was required to coordinate the research, development and production of all such devices for aircraft.[63]

[63] PRO Air 20/8953, p.5.

6. Fighter and Bomber Commands

The Royal Air Force functional Commands were created in 1936 and, in July of that year, Sir Hugh Dowding was appointed the first Air Officer Commanding-in-Chief of Fighter Command.[64] He had been Air Member for Supply and Research since September 1930 and, was, briefly, Air Member for Research and Development, before taking up what was to prove his most formidable task as a serving officer. He was thus in an ideal position to watch the growth of radar, encourage its development and promote its deployment. Under his leadership Fighter Command became an efficient and fully integrated air defence organisation, complete with radar early warning, fighters, communications, barrage balloons, observers and anti-aircraft guns; it was thus well placed to protect the United Kingdom when it was most needed. With regard to Bomber Command, it was a different story. For the same economic reasons as those which made the politicians favour the production of less costly fighter aircraft, bomber production was less favoured than that of smaller and lighter aircraft. Consequently, Air Staff plans for heavier aircraft were not always approved and manufacture was either delayed or scaled down. As a consequence of financial restraints and the Air Ministry's belief that the bomber would always get through, there was little incentive for research and development. Consequently, Bomber Command was neither well trained in navigational and bombing techniques, nor equipped with suitable aircraft. It was thus incapable in 1939 of bombing targets accurately in Germany and inflicting any meaningful damage on German industry.

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[64] Denis Richards, *Royal Air Force 1939-1945*, vol.1, p.404.

Bomber Command's first Air Officer Commanding-in-Chief was Air Chief Marshal Sir John M. Steel, GCB, KBE, CMG, but his tenure was destined to last only a little over a year. Sir Edgar Ludlow-Hewitt replaced him at the time of the Munich crisis. The Command was not only short of heavy bombers but of aircrew as well. Moreover, crews were unable to navigate accurately, especially by night. In the circumstances the recently introduced policy of only attacking military targets, in the event of an outbreak of war, was generally welcomed by the AOC-in-C. Not surprisingly, the Air Ministry was now allowed by the government to order as many aircraft as could be produced and, as fighters were quicker and cheaper to manufacture, the benefits of this decision fell to Fighter Command. The Air Ministry was well aware of the danger of expanding the force too quickly, but time was short. Due to years of disarmament and financial stringency, half of the aircraft of Bomber Command lacked the range to attack Germany from bases in the United Kingdom.[65] Given a numerically superior German Air Force, Bomber Command thus could do little else but delay the onset of a policy involving all-out attack for as long as possible.[66] Even the Chief of Air Staff, Sir Cyril Newall, was compelled to acknowledge on the outbreak of war that Bomber Command was too weak to launch an offensive against Germany.

7. Development of Radar in Germany

A German national, Christian Hulsmeyer, first patented a radar device in 1904.[67] It was not very efficient and some twenty-

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[65] Richard Overy, *Why the Allies Won*, p.107.

[66] C. Webster and N. Frankland, *The Strategic Air Offensive Against Germany 1939-1945*, vol.1, pp.100-101.

[67] David Pritchard, *The Radar War*, p.14.

five years were to elapse before the necessary technology became available for the principles involved to be incorporated into a practical device. A Professor Braun had built a cathode ray tube as early as 1897, and in 1924 pulsed wireless signals were utilised to find ranges of objects. These advances were followed by the work of Dr Yagi of Japan who in 1929 showed how wireless signals could be transmitted for the very first time in fine beams employing directional aerials. By 1933, Dr R. Kuhnold, of the German Navy's Research Department, had been experimenting with radar; a year later the Gema Company began constructing his detection devices. Subsequently improvements to prototypes led him to employ pulsed transmissions operating on 600 Mcs. The upshot was that in 1935 ships could be detected at five miles and coastlines at twelve, the device becoming known in Germany as Dezimeter Telegraphie or DT-Gerät. In 1936 the operating frequency was altered to 150 Mcs, with the result that aircraft could be detected at ranges up to thirty miles. Eventually, Dr Kuhnold produced the Freya early warning radar initially operating on 125 Mcs, which by the end of 1936 could detect aircraft at a range of fifty miles.[68] By the summer of 1938 Freya was ordered first by the German Navy, who took possession of their initial equipments in 1938. It was then ordered by the Air Force. Good though Freya was as an early warning device, the German Navy wanted an accurate gun-ranging device. The Gema Company obliged by producing Seektakt, an early model of which, working on a frequency of 375 Mcs, gave a range of nine miles. By the summer of 1938 it was fitted to the pocket battleship *Graf Spee*, and the *Scharnhorst* and *Gneisenau* by November 1939. By contrast, at the beginning of the war only two

[68] Ibid., p.49.

ships of the Royal Navy possessed radar, both Type 79 air-warning sets.[69] The Telefunken Company too, was interested in radar and entered the field in 1936. Perhaps they had spotted a niche in the market, for Freya lacked a height-finding capability. The result was the highly mobile and accurate Wurzburg set which arrived in 1938. It could plot aircraft to within very fine limits at ranges up to 25 miles, operating on 560 Mcs, and was a very accurate device indeed. At the same time Telefunken designed and built a small airborne radar set, trials beginning in the summer of 1939 with Ju 52 aircraft. Some of this information found its way back to British Intelligence, but was largely dismissed on the grounds that, because radar was a British invention, it was unlikely that Germany could have developed the device so quickly.

8. Development of Radio in Germany

It was Erhard Milch, who shortly after becoming a Director of Lufthansa in 1925, insisted on blind-flying training for his pilots and asked German industry to provide the necessary instruments.[70] With this in mind it should not come as any surprise to find that use of wireless aids to assist with navigation was strongly advocated in Germany before World War Two. Consequently, during the 1930s some twenty-four medium frequency beacons were established; by September 1940, this figure had risen to thirty-eight. These devices transmitted a call sign followed by a twenty-second continuous note, enabling the crew of the aircraft to obtain a bearing on the known location of the beacon. Frequencies employed were in the range 176-580 Kcs, and

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[69] Len Deighton, *Blitzkrieg*, p.118.

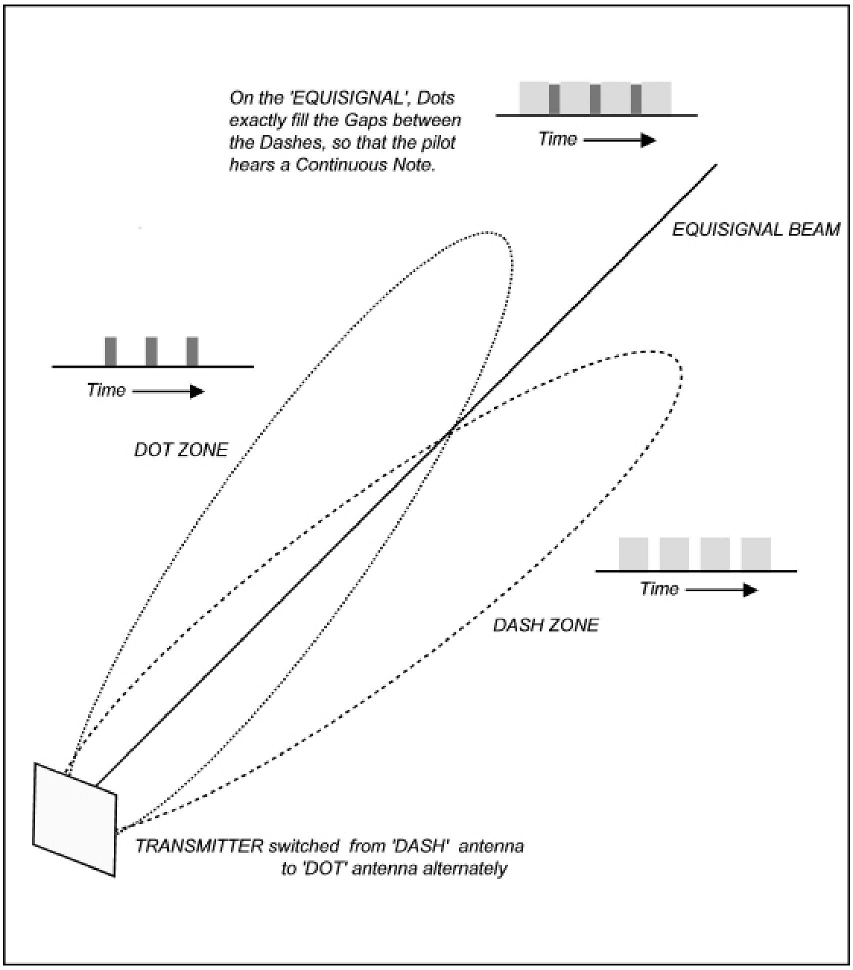
[70] David Irving, *The Rise and Fall of the Luftwaffe*, p.19.

the information obtained was used to confirm turning points, and for homing, as well as general navigation.[71]

As early as 1933, the German wireless industry had anticipated the future needs of a German Air Force by starting to experiment with various forms of wireless aids which could possibly be used for navigation and bombing purposes, even when aircraft were supporting the German Army in the field.[72] Indeed, the Lorenz Company evolved a short-range airfield approach system, employing very high interference-free frequencies (VHF). Morse dots were heard to one side of the beam, and dashes to the other; a steady note was heard when the beam was being followed. Unlike modern equipment, no glide path facility was fitted, but in the horizontal plane the beam was very accurate. In the United Kingdom the Lorenz system was known at first as Standard Blind Approach, and, later, as Standard Beam Approach. Lufthansa, the Luftwaffe, the Royal Air Force and others adopted this 'blind' landing device. It was believed at the time that these VHF transmissions were limited to a range of about 20-30 miles for an aircraft flying at about 2000 feet. (See Figure 1). Unknown to the Royal Air Force, the Germans had discovered that with a powerful VHF transmitter, coupled with an appropriate aerial array, signals could be received at distances of up to 250 miles by aircraft flying at 20,000 feet. With the aid of a second transmitter, located so as to provide an intersection over the target, Lorenz had developed a blind bombing device for the Luftwaffe, operating on 30.0 to 33.3 megacycles (Mcs), with beam widths of 0.33 degrees. This device was given the name Knickebein. Little additional training was

[71] F.H. Hinsley, British *Intelligence in the Second World War*, vol.1, pp.550-551.

[72] Ken Wakefield, *Pfadfinder*, pp.4-5.



R.V. Jones

Figure 1

Diagram explaining principle of Lorenz Beam which, at the time was thought to have a maximum range of some fifty miles required by German aircrew as the receiver was incorporated in the standard airborne beam approach equipment FuBl 1, and could therefore be used by the crews of all Luftwaffe bomber aircraft fitted with standard blind approach equipment.[73] (See Figure 2)

While Telefunken GmbH was manufacturing Knickebein, Lorenz commenced work on another VHF blind bombing system, X-Verfahren. It was developed at Rechlin by a team led by Dr Hans Plendl and comprised a complex multi-beam device using 66.0-77.0 Mcs. The track to be followed was one of fourteen, usually seventh from the left, and was adjusted for crosswind over the target; the others were false or decoy beams. Lorenz, Telefunken and Siemens all contributed to the development of X-Gerät or Airborne Equipment. Dot-dash keying facilities were employed akin to those of Knickebein, but the beams were much narrower, being only 1 Km wide (1,100x) at a range of 100 Kms (62 miles). The beams, however, were made up of 180 directional signals per minute and required an analyser to decode them, making interference unlikely, even if the beam in use could be identified. Until 1941, the device included two Telefunken Anna VHF receivers, two associated aerials with separate masts, two Siemens signal analysers, an inverter, a power distribution panel, two course meters and an automatic bomb-releasing clock, or X clock. To carry out a blind bombing attack required an operational aircraft, normally a Heinkel HE 111, complete with this equipment and a specially trained crew. In 1938 therefore the Luftwaffe had a second blind bombing device, albeit at the time fitted into Junkers Ju 52/3m. By 1939 it had the potential to form and utilise a pathfinding force with its latest equipment. Not

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[73] Ibid. pp.5-9.

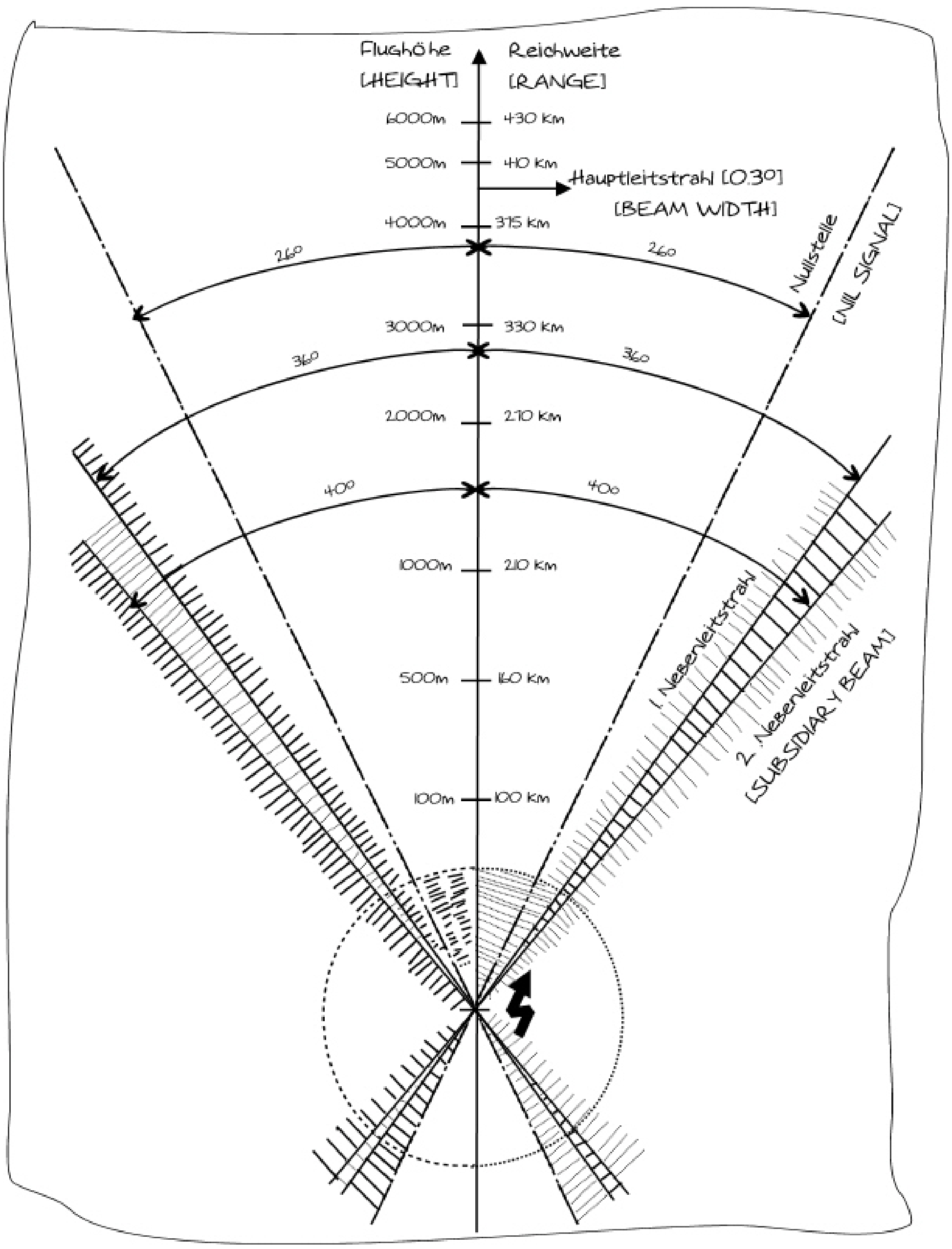

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Figure 2

Copy of Knickebein Document

Captured in July 1940

content with Knickebein and X-Verfahren, Germany decided to develop another precision blind bombing system. This was Y-Verfahren, devised by Dr Plendl at the Rechlin Test Centre; it was technically more advanced than the other two devices, and it was also considerably more accurate. It employed a single VHF beam for guidance to the target, the aircraft's position being determined electronically by a second transmitter, employing range or distance equipment. Using Y-Verfahren, or Benito, it was necessary for a ground controller to pass a bomb release signal when the aircraft was over the selected target.[74] (See Figure 3)

So German radar developed completely independently of the British and for different reasons. Germany wanted Radar for coastal defence and for their warships, together with an early warning radar and an accurate height-finding device with which to control guns and searchlights. Britain, on the other hand, wanted a Chain Home and Chain Home Low system for fighter defence. In the United Kingdom these requirements were given a high priority. In general German equipment was better designed and produced. The architects of the Luftwaffe always intended that it should be a balanced air force, consisting of fighters, bombers and transport aircraft, capable of supporting the German army. By 1936, Dornier had already built prototypes of the Do 19 and Junkers the Ju 89. Goering, however, scrapped both aircraft and all four-engined aircraft in 1937.[75] By the time this mistake was recognised a year later, and the He 177 was ordered as a substitute, with the proviso that it should be capable of dive-bombing, it was too late to affect

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[74] Ibid., pp.49-51.

[75] David Irving, *The Rise and Fall of the Luftwaffe*, pp.45, 54-55, 66.

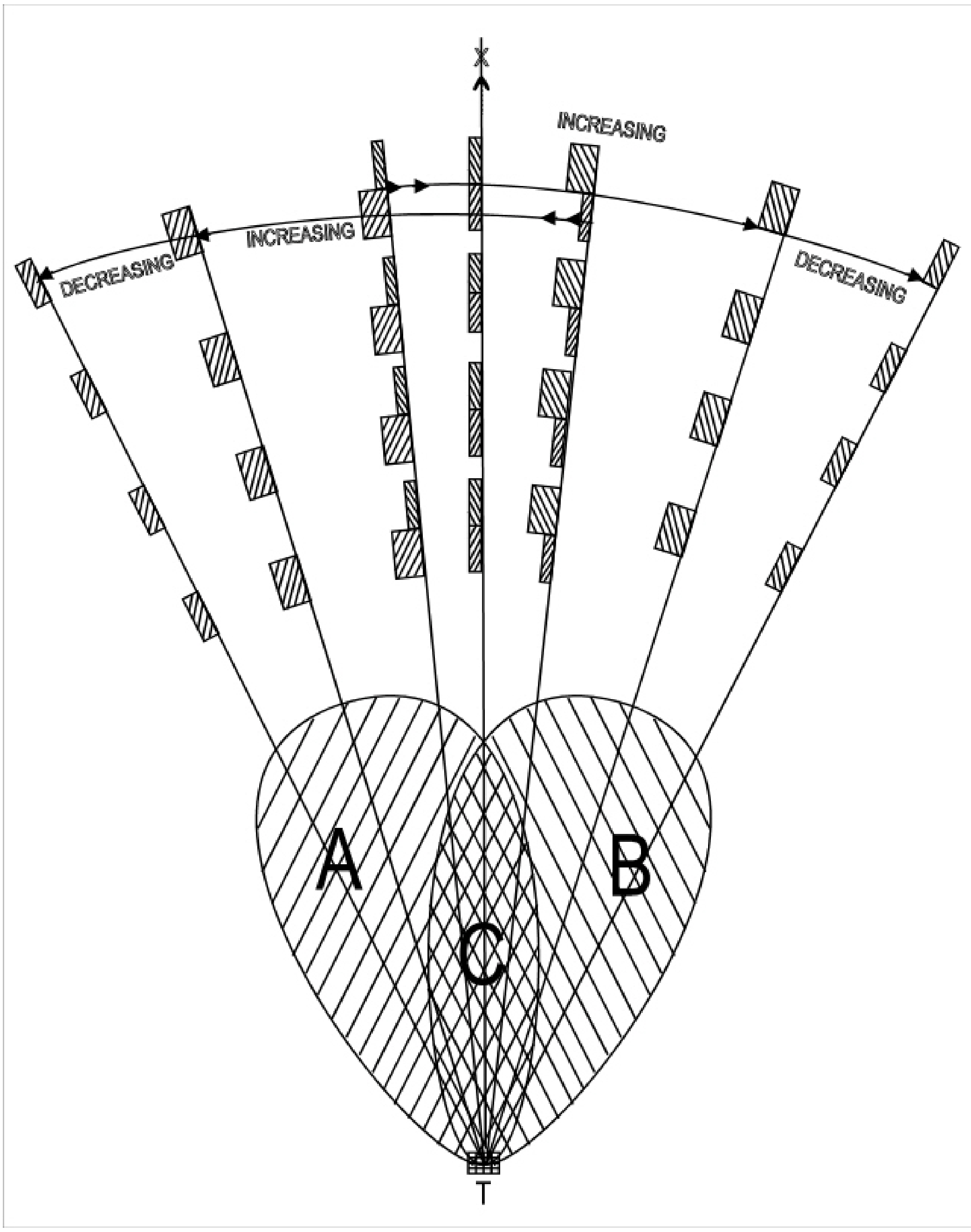

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Figure 3

Diagram of Benito System

the strategic bombing of the United Kingdom.[76] By default therefore, the Battle of Britain and the subsequent night-time Blitz, had to be conducted by the Luftwaffe with what, essentially, was a tactical air force. Now that the historical development of radar has been discussed as essential background to the thesis, I will investigate just exactly how the British discovered the German beacons and beams and establish what they did about it.

[76] Ibid., p.66.

CHAPTER TWO: GERMAN BEAMS AND BEACONS

1. KGr 100, X-Verfahren and Knickebein

In Germany in March 1939, selected aircrews were receiving training in the use of the X-Verfahren system. This was a wireless navigation and blind bombing beam. Heinkel (He) 111 aircraft were employed and practice bombs were being dropped on targets, with the aid of X-Gerät equipment, from heights as high as 28,000 to 30,000 feet, often with accurate results. The unit concerned, LnAbt 100, made sufficiently good progress for it to be declared operational by 1 September 1939, in time for the attack on Poland.[1] X-Gerät was thus used operationally for the first time against military targets by day and by night, the crews concerned gaining valuable experience with this device. Soon after the outbreak of hostilities, the Luftwaffe was conducting reconnaissance and limited anti-shipping strikes over the North Sea and against elements of the British fleet based on the Firth of Forth. On 18 November 1939, the Luftwaffe unit concerned became a bomber wing, KGr 100, and when the tempo of these operations was increased, the opportunity was taken to hold Knickebein (a more elementary wireless navigation and blind bombing beam) and X-Verfahren trials over France and the East Coast of Britain in order to prepare for the forthcoming bombing campaign. To support these activities the existing M/F beacons and Knickebein transmitters were augmented by appropriate X-Verfahren transmitters positioned near Baden Baden, Krefeld and on the island of Borkum.

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[1] Ian Kershaw, *The 'Hitler Myth': Image and Reality in the Third Reich* (Clarendon Press, Oxford, 1987); Ken Wakefield, *Pfadfinder*, p.16.

2. Denmark, Norway, the Blitzkrieg and Dunkirk

On the earlier advice of Admiral Raeder, Hitler authorised preparation of a detailed plan for the seizure of Norway on 17 January 1940.[2] Warnings of Operation Weser Rubung had been received in Whitehall but largely ignored and thus the invasion of Denmark and Norway on 9 April achieved total surprise.[3] KGr 100 took part in this operation but, somewhat surprisingly, without its X-Gerät equipment.[4] Just over a month later German forces attacked in the West, frequently employing Blitzkrieg tactics, with the result that Belgium, Holland, Luxembourg and France soon fell to the combined effects of the German Army and Air Force.[5] The British Expeditionary Force (BEF) was forced to retreat and leave most of its heavy guns and transport behind, together with two Type-X cipher machines, without, fortunately for the British, their all-important cipher wheels. By early June 1940, less than one month from the start of the German assault, much of the BEF had been evacuated from the continent of Europe though at considerable cost in aircraft, especially Hurricane fighters, ships, and men.[6]

3. Knickebein Revealed

Shortly after the catastrophe at Dunkirk in May and June 1940 GC&CS, at its new headquarters at Bletchley Park successfully decoded an Enigma message referring to a radio beam

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[2] Ibid., p.20.

[3] F.H. Hinsley, *British Intelligence in the Second World War*, vol.1, pp.115-117.

[4] Ken Wakefield, *Pfadfinder*, pp.21-22.

[5] Ian Kershaw, *The 'Hitler Myth': Image and reality in the Third Reich*, p.152.

[6] Martin Gilbert, *Winston S. Churchill*, vol.6, pp.406-407.

situated near Kleves, the nearest part of Germany to the United Kingdom.[7] To Dr R.V. Jones, the brilliant scientist of RAF Scientific Intelligence at the Air Ministry, this news, together with that obtained from the interrogation of prisoners of war and examination of German radio equipment taken from crashed aircraft, confirmed the existence of a system of narrow radio beams used for navigation and bombing. Moreover, the disclosures in 1939 contained in the Oslo Report of, inter alia, a description of a radar early warning system and the finding of a radio rangefinder aerial with an operating frequency of 57 or 114 cms on the *Graf Spee* by L.H. Bainbridge-Bell, strongly suggested to Dr Jones that the Germans were fully capable of producing radar - if they did not already possess it. His opinion, however, was not universally accepted in London.[8] In accordance with thinking at the time, doubt was also expressed that radio waves transmitted from Germany in the 30 megacycle band, and similar to those used for the Lorenz landing beam, could be employed for such purposes over the United Kingdom, especially as the maximum range of these radio beams was considered to be around 50 miles, at most.[9] Sir Henry Tizard was among those who expressed the view that the beams could not provide pinpoint accuracy over the ranges envisaged and, because of this, he considered that far too much

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[7] R.V. Jones, *Most Secret War*, pp.92-94.

[8] PRO Air 20/1622 ASIR Report No.5 dd. 23 May 40; F.H. Hinsley, *British Intelligence in the Second World War*, vol.1, pp.508-512. The Oslo Report sent anonymously to the British Naval Attaché in Oslo in November 1939 was one of the most remarkable intelligence reports of the entire war. It disclosed, inter alia, the existence of the new German bomber aircraft the Ju88, and its production program, the presence of the secret Luftwaffe laboratories and test range at Rechlin, and that German radar provided early warning of the RAF attack on Wilhelmshaven, 4-5 September 1939.

[9] Ronald W.Clark, *Tizard*, (Methuen and Company Limited, 1965), p.230.

excitement was being generated about the whole affair.[10] Nevertheless, since this frequency band was one utilised by German blind landing receivers, installed in Luftwaffe bomber aircraft, the system could be used routinely by aircrew of the bomber force.[11] It was known as Knickebein (or Crooked Leg) to the Luftwaffe and by the code name Headache to those involved with such matters in the United Kingdom.[12]

In spite of the fact that the Standard Telephone Company owned the rights to the Lorenz system, the pre-war RAF possessed nothing like it.[13] Although the Blind Approach Training and Development Unit was formed at Boscombe Down on 29 September 1939, Blind Approach Training was only introduced to the service in general in January, 1940, some five months after the outbreak of war.[14] Moreover, the necessary instrumentation for operational aircraft was not fitted until the following December.[15] On 15 June, 1940, with a defeated Army at home, almost bereft of its heavy guns and equipment, and an invasion expected daily, a meeting was held at the Air Ministry under the chairmanship of Air Marshal Sir Philip Joubert, who had been appointed the day before by the Secretary of State, Sir Archibald Sinclair, to take charge of the investigation into the German beams.[16] At this meeting it was decided that there was sufficient evidence of beam activity to take

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[10] Ibid.

[11] PRO Air 41/46 App.“A”.

[12] PRO Avia 7/779; PRO Avia 26/407.

[13] John Ray, *The Night Blitz 1940-1941*, p.124.

[14] Norman Longmate, *The Bombers* (Hutchinson, Norwich, 1983), p.68.

[15] Tim Mason, *The Secret Years*, p.310; Directorate of Public Relations (RAF), *Chronology* (MOD, 1963), p.16.

[16] R.V. Jones, *Most Secret War*, pp.95-96.

immediate action. It was not long in coming. The following afternoon, at a further meeting, the Director of Signals was authorised to form a flight of aircraft for the purpose of finding the beams. Other decisions were: Watson Watt and R.V. Jones to inquire into the possibility of placing receivers on Chain Home radar towers and Group Captain L.F. Blandy, a Deputy Director of Signals and head of the RAF 'Y' Service, to evolve a method of jamming the Knickebein transmissions.[17] Such jamming required the production in the output of the enemy receiver, of sufficient energy to prevent recognition of the wanted signal.[18]

Under the threat of German airborne and seaborne landings, Blandy quickly created a section in the Air Ministry to deal with the jamming of German wireless beams and placed Wing Commander E.B. Addison, a signals specialist, in charge of such activities.[19] Accordingly, American Hallicrafter receivers were purchased at an appropriate radio retailer, as none were available from RAF sources, and placed on five of the Chain Home's radar masts, by now three hundred-feet high, in an attempt to intercept the beams from the ground.[20] (See Figure 4) Subsequently, the listening watches were regularised and placed on a formal basis; and later, when it was established that the current scientific theory was invalid, and that the German beams could indeed be used over the United Kingdom for the purposes envisaged, the network was extended inland. It was also decided to re-form the recently disbanded Blind Approach Training and Development Unit (the

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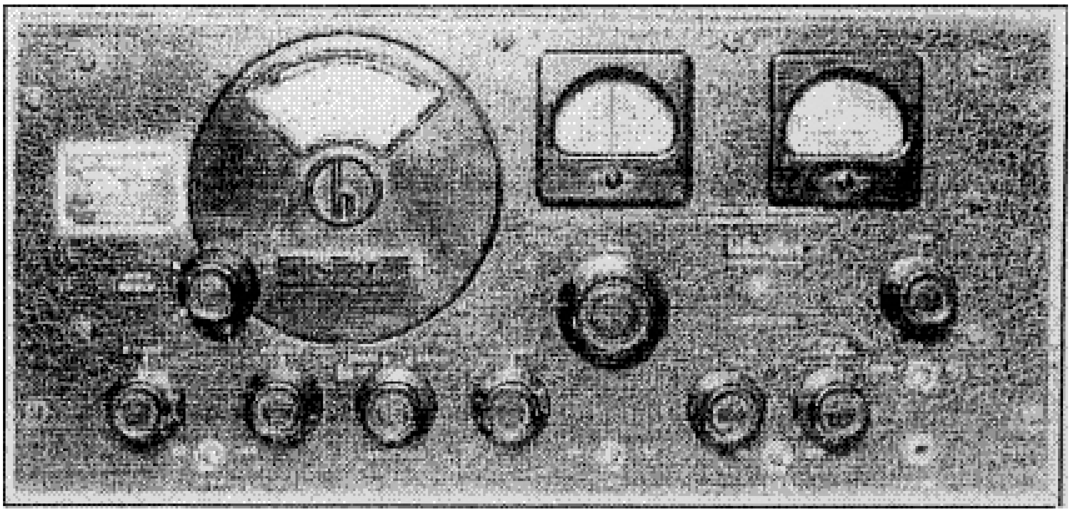
[17] Norman Longmate, *The Bombers*, p.68; PRO Air 20/8953, p.38.

[18] PRO Air 26/280; PRO Air 26/580; PRO Avia 7/779.

[19] PRO Air 26/280; PRO Air 26/580.

[20] R.V. Jones, *Most Secret War*, p.97.



Brian James

Figure 4

Ultra High Frequency Radio Receiving Equipment
Hallicrafters S 36

only one) as the Wireless Intelligence Development Unit (WIDU) at Boscombe Down, near Salisbury, with a detachment at RAF Wyton, in Huntingdonshire.[21] The aircraft establishment of the new unit was increased to eight Ansons and three Whitleys, with a corresponding increase in air and ground crews.[22] RAF pilots experienced in beam flying made up the nucleus of the new unit, which was commanded by Wing Commander R.S. Blucke.[23] Among the first aircraft made available for the air investigation was an Avro Anson, fitted with Lorenz blind landing apparatus. In an attempt to hear beam signals from the ground, a van was obtained and fitted with a United States Hallicrafter radio receiver and, for crude jamming purposes, a hospital diathermy jammer set tuned to 31.5 Mcs. The remainder of the month was spent searching for proof of Knickebein activity and deciding on the best policy for interfering with the beams effectively, when found.[24] Two days later, further information from intelligence sources confirmed the position of the Knickebein transmitters in Germany at Kleves and at Bredstedt.[25]

On the third day of the air search, during the evening of the 21 June, 1940, the beams were found on the expected frequencies of 31.5 and 30.0 megacycles, respectively, by an Anson aircraft of the newly formed WIDU, captained by H.E. Bufton.[26] (See Figure 5) Three nights later, one of the tower listening stations reported

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[21] For a good description of life at Boscombe Down at the time, see Tim Mason, *The Secret Years*.

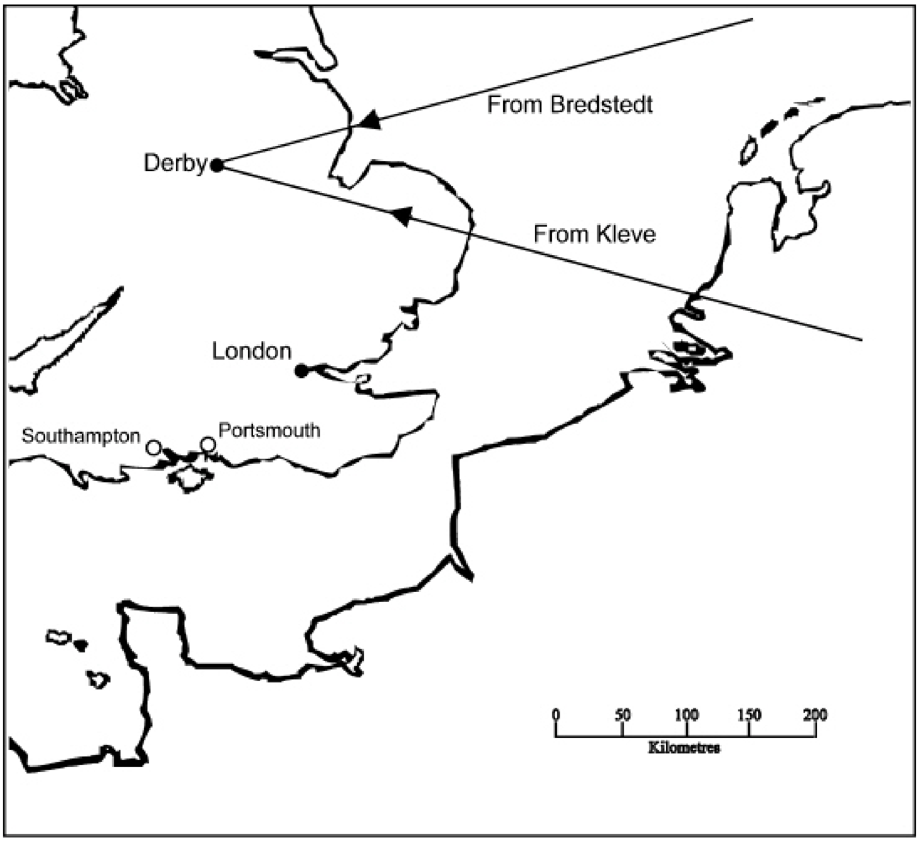
[22] Michael Cumming, *Beam Bombers*, p.15.

[23] PRO Air 26/580.

[24] PRO Air 20/1623; PRO Air 20/1626; PRO Air 41/46 and App.“A”.

[25] PRO Air 41/46, p.4.

[26] PRO Air 20/1624.



R.V. Jones

Figure 5

Knickebein Beams found evening 21st June, 1940 hearing beam type signals on similar frequencies. With an elementary listening system in place, countermeasures could now start to be devised. While the listening facilities were being organised, emergency action was taken against the Knickebein beam itself. A number of electro-medical (diathermy) sets were borrowed from local hospitals and used as crude jammers, two of the appliances being modified to cover 30 mcs, but without keying facilities. They were placed in vehicles, containing receivers for intercepting beam signals and sent Wyton in Huntington and to Boscombe Down in Wiltshire, for dispatch to any specified target area.[27] Tests by No 109 Squadron, however, indicated that the selected sets were unlikely to be successful. Further apparatus was thus obtained from similar sources, twelve of the most suitable being altered for the purpose and provided with audio modulation. They were deployed at police stations on the East and South Coasts and controlled from H.Q. Fighter Command.[28] A few days later Intelligence confirmed the existence of Freya, a German Early Warning radar, and the X-Verfahren (Wotan I) and the more advanced Y-Verfahren (Wotan II) navigation and bombing devices, which came as a shock in London. About the same time, intelligence was received about a new Knickebein transmitter to be set up in the Cherbourg and Brest area of France. The conclusion drawn was that the Germans clearly intended to make full use of all these systems in order to expedite the forthcoming bombing campaign against the United Kingdom. Hence the rush by the Germans to erect appropriate aerials in northwest France and Holland, as quickly as possible. As mentioned earlier, there had been insufficient time for Luftwaffe signals personnel to erect

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[27] A.I.1 (e) Reports 26 June 1940 and 28 June 1940, quoted in PRO Air 41/46, pp.4-5.

[28] Ibid.

Knickebein equipment during the rapid Polish campaign, however, the smaller and more mobile X-Verfahren was deployed and used operationally.

Before appropriate jamming equipment could be designed and produced, it was essential to know as much as possible about how Knickebein worked. Information from prisoners of war, maps from aircraft that had crashed in the United Kingdom and Enigma decrypts provided valuable clues about Knickebein. It was thus believed at the time that the early Knickebein was capable of being directed to a specific location over the United Kingdom, within an accuracy of 0.1 degree, thus enabling the crew of an aircraft to find a target in adverse weather conditions by day or night. The airborne receiver was incorporated in the standard Lorenz landing beam equipment, E.Bl.1, or Empfänger Blind 1. The early mark of the ground transmitter comprised two aerial arrays set at an angle of 165 degrees, each array consisting of two stacks of eight vertical, centre-fed full-wave wire aerials, complete with reflectors, operating on the fixed frequencies of 30 and 31.5 megacycles. The aerials were attached to a framework 315ft by 100ft that could be rotated in the direction of the target with the aid of wheels. Interlocked dots and dashes were then transmitted by this system on the audio frequency of 1150 cycles per second as complementary signals. Along the three-degree width equi-signal, a continuous note could be heard in a receiver, while dots could be received on one side and dashes to the other. Discrimination in determining the continuous note gave the effect of a beam. Morse keying occurred at a rate of 60 characters per minute and the ratio between the duration of the dot and the dash was 1/7. As was to be expected with VHF transmissions, the range of Knickebein varied with the height of the aircraft.[29] By the use of two Knickebein transmitters it was possible to arrange for the beams to meet over the intended target. Indeed, intelligence had already suggested that these were positioned at Bredstedt, Husum and Kleve. The Germans subsequently installed a number of Knickebein transmitters along the coast of the Continent, adjacent to the British Isles, thereby reducing the height at which their aircraft would otherwise have to operate, when attacking industrial and other targets situated in the United Kingdom.[30] (See Figure 6)

4. Luftwaffe M/F Beacons and RAF Countermeasures

In July 1940, the usually accepted view held in the United Kingdom was that medium frequencies were not suitable for accurate navigation purposes at night, because of poor propagation leading to inaccurate bearings. Nevertheless, a further decision was taken that month to prevent the Luftwaffe from using the well-known pre-war network of medium frequency radio beacons, which was now being extended to cover the occupied countries and the United Kingdom. By March, 1940, some forty-six were in operation and Sir Hugh Dowding, AOC-in-C Fighter Command, had good reason to believe that the Luftwaffe could be using the beacons as an aid to navigate accurately to targets situated in the United Kingdom.[31] In order to put a stop to this, a system of masking German beacons was introduced.[32] The Radio Branch of the GPO had earlier devised this masking, or Meacon, system for a slightly

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[29] Alfred Price, *Instruments of Darkness*, p.23.

[30] PRO Air 41/46 App."A".

[31] PRO Air 20/8963, Enclosures 4A and 5A.

[32] PRO Air 41/46, p.8.

KNICKEBEIN

		PLACE	FREQUENCY Mcs	POSITION	FIRST PHOTOGRAPH	FIRST HEARD
LUFTFLOTTE 2	Kn.1	KLEPP, STAVANGER	30 or 31.5	58° 46´ 10"N, 05° 37´ 30"E	29.9.40	-
	+Kn.2	STOLLBERG	30	54° 38´ 42"N, 08° 56´ 42"E	1.9.41	-
	Kn.3	JULIANDORP	33.3	52° 54´ 40"N, 04° 43´ 00"E	10.3.41	Nov. 1940
	+Kn.4	KLEVE	31.5	51° 47´ 24"N, 06° 06´ 12"E	15.10.40	June 1940
	Kn.5	BERGEN-OP-ZOOM	31.5 or 33.3	51° 27V 03"N, 04° 18´ 02"E	24.9.41	? Oct. 1941
	Kn.6	Mt. VIOLETTE	30 or 31.5	50° 37´ 05"N, 01° 40´ 58"E	21.6.41	May 1941
LUFTFLOTTE 3	Kn.7	GRENY	30 or 31.5	49° 57´ 42"N, 01° 17´ 30"E	1.10.40	Aug. 1940
	Kn.8	Mt. PINCON	30 or 31.5	48° 58´ 22"N, 00° 37´ 13"W	17.6.41	May 1941
	Kn.9	BEAUMONT-HAGUE	30 or 31.5	49° 40´ 29"N, 01° 51´ 16"W	18.9.40	Aug. 1940
	Kn.10	SORTOSVILLE-EN-BEAUMONT	30 or 31.5	49° 25´ 04"N, 01° 42´ 32"W	3.7.41	May 1941
	Kn.11	MORLAIX	30 or 31.5	48° 40´ 00"N, 03° 43´ 50"W	4.1.41	Oct. 1940
	+Kn.12 (?)	LÖRRACH/HÖLSTEIN	-	47° 38´ 01"N, 07° 45´ 54"E	13.5.44	-
	Kn.-	NOTO, SICILY	-	36° 55´ 44"N, 14° 58´ 45"E	5.8.42	-

Note 1 Knickebein marked + were the large type

Note 2. Numbers were those used from 1941 onwards.
Frequencies were those used before the multiple frequency scheme in 1941 was introduced.

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Figure 6
Known Knickebein Locations

different purpose.[33] Frequencies could be altered quickly, the transmitters being designed to re-radiate the German beacon signals thus making it difficult, or impossible, for these to be used for accurate Direction Finding and navigation purposes.

While the Meacon scheme was being developed, it was intended, as an emergency measure in case more jamming capacity should be required, to earmark some one hundred T.77 transmitters, already installed at RAF stations for normal communication purposes. In this way the whole of the country could have been covered in clusters or groups of RAF jammers, each of which would have been capable of dealing with German beacons. The need, however, for this measure did not arise and the scheme was never implemented.[34] The first Meacons were ready during July, at the start of the Battle of Britain.[35] Air tests were conducted immediately to prove the efficacy of the first station based at Flimwell, near Tunbridge Wells.[36] (See Figure 7) Full results of the tests, however, were not available until two months later when they indicated that crews of Luftwaffe aircraft, whilst over the United Kingdom, could experience errors of between 9 degrees and 59 degrees when using beacons based in France.

Early in the following month, Dowding wrote a letter to the Under Secretary of State for Air asking for immediate action to be taken against these beacons.[37] Fortunately, this requirement had

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[33] Post Office Eng. Dept. Radio Reports Nos. 597, 598 and 599, Post Office Instruction GB1, the GB Scheme, quoted in PRO Air 41/46, p.7.

[34] PRO Air 26/580, p.2; PRO Air 20/8953 E.4A.

[35] PRO Air 41/46 pp.7-8; PRO Air 41/46 App.“C”, Fig.1; PRO Air 26/580.

[36] Laurie Brettingham, *Beam Benders, Royal Air Force No 80 (Signals) Wing 1940-1945*, p.18.

[37] PRO Air 26/580; PRO Air 20/8963, E.4A.

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Figure 7

Meacons & German M/F Beacons

been foreseen by the BBC and the GPO, and more powerful Meacons designed. Some fifteen equipments were thus operating by the end of the month. These were positioned at Flimwell, Harpenden, Templecombe, Henfield and Petersfield. Air tests continued during the Meacon build-up period and at the same time comparative field strengths were obtained of German beacons and RAF Meacon equipment.[38] Such was the concern, however, felt about the threat posed to the United Kingdom by the employment of these aids that, at one time, use of the BBC's high-powered transmitters was contemplated for jamming the whole band of frequencies employed by the German Medium Frequency system. Ten transmitters would have been required, the frequency of each transmitter being modified to vary over a band of between 30 to 40 Kcs. But unless these had been operated in synchronised groups of at least three, the Luftwaffe could have used them as beacons for its own crews, thus outweighing any advantage of employing them as jammers.[39]

The RAF airmen operating the Meacon equipment needed much skill. Not only were they required to be fully conversant with the Meacon itself, but had to be aware of the German call-signs and the frequencies allocated to German beacons, together with their radiated power and location. Moreover, the success of the system was jeopardised every time the Germans switched frequencies and/or beacons.[40] Fortunately the RAF Y 'Listening' Service, especially No. 61 Wireless Unit, under the command of Wing Commander W.G. Swanborough, based at RAF Cheadle,

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[38] Ibid.

[39] PRO Air 40/2242.

[40] PRO Air 41/46, p.8; Ted Sweet, *Enemy below!*, pp.27-28.

knew both the frequency and the make-up of the Luftwaffe call-signs.[41] Other factors also had to be taken into consideration. The allocation of meacons to German beacons by the RAF Controllers depended on the following: the number of Luftwaffe beacons in use at any one time, the intended target or aircraft tracks, the power of available meacons, the extent meacon transmissions would affect bearings of beacons of different power, and the fact that meacons could not be employed if sited on a line joining a German beacon and the aircraft concerned, together with a number of technical matters such as frequency spacing, harmonic values and receiver capabilities.

5. Formation of No 80 (Signals) Wing

On 25 July, 1940, early in the first phase of the Battle of Britain, while Luftwaffe aircraft were attacking convoys in the channel, the Assistant Chief Of Air Staff (Radio) called a meeting at the Air Ministry, to discuss how radio countermeasures against Knickebein and the German beacons could best be organised. It was decided that the useful application of such measures could only be achieved by an officer having a complete knowledge of German aircraft movements over or near the United Kingdom. Early control was thus placed in the hands of HQ Fighter Command. It soon became apparent, however, that RAF radio countermeasures would be required on an ever-increasing scale, involving a much greater organisation than hitherto envisaged. Consequently, at a similar meeting held four days later, a decision was taken for the establishment of a special formation, to be known as No. 80 (Signals) Wing, which would assume

[41] Aileen Clayton, *The Enemy is Listening*, p.60; PRO Air 20/163 and App.11; F.H. Hinsley, *British Intelligence in Second World War*, vol.1, p.323.

responsibility for all RAF radio countermeasures and come under the direct operational control of the Air Ministry.[42] Command of the Wing, which came into existence on 29 August 1940, was entrusted to a signals specialist, Wing Commander E.B. Addison. Regular countermeasures, however, had started slightly earlier from Garston on 20 August 1940.[43]

6. Target Prediction

While further arrangements were being prepared for countering the beams, an analysis of the signals intercepted by the Wireless Intelligence and Development Unit (WIDU), and by the ground stations, was undertaken. From these results it was confirmed that the first of the German signals had indeed originated from the area around Kleves, but that the Morse characteristics received at the various receiver sites in the United Kingdom were not always in the usual sequence.[44] A theoretical diagram of an aerial array capable of producing such an effect had already been produced, when a Knickebein document was recovered from a crashed German aircraft in July 1940. This furnished details of the main beam and subsidiary beams, together with the relevant heights and ranges.[45] When the diagram and the document were compared, the theoretical diagram was found to agree closely with the captured document. It was then realised that it might be possible to establish the setting of the main beam in advance of the actual attack, if the angular positions of the side beams were known and if, thanks to the reliable signal being

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[42] PRO Air 41/46, p.10.

[43] PRO Air 26/580, p.3.

[44] PRO Air 26/407; PRO Air 26/580; PRO Avia 7/779.

[45] PRO Air 20/162.

received by tower receivers, sufficient ground observations could be obtained.[46] In order to determine the target area a copy on tracing cloth, as accurate as possible, was made of the German beam pattern. This was then placed on to an appropriate map with the centre of the pattern on the Knickebein transmitter site and rotated until the characteristics obtained at the various ground sites matched those of the diagram. The direction of the main beam could then be ascertained and an immediate indication provided of the towns and cities over which the beam passed.

The process was repeated with a second Knickebein beam originating from a different location: where the two crossed revealed the intended target area. This method was found to be reliable and the information so gleaned was passed without delay to the duty Air Commodore at HQ Fighter Command.[47] Here, action could be taken to strengthen the local air and ground defences, where this was deemed to be appropriate. Soon confirmation was received of the increase in the number of Knickebein transmitters constructed by the Luftwaffe, as foretold by Enigma; indeed during the last week in August, 1940, two more beam stations were identified by aircraft of the Wireless Intelligence Development Unit (WIDU), one near Dieppe and the other near Cherbourg. Both operated on a frequency of 30 Mcs. Information was also provided about a Knickebein transmitter site being erected at Stavangar, Norway. Heavy German air raids took place over the United Kingdom in August, and from the radar tracks of the participating aircraft it was deduced that the Kleves and Dieppe transmitters were used to mount attacks against London, while the

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[46] PRO Air 41/46, pp.5-6, p.15.

[47] Ibid.

Knickebein at Dieppe and Cherbourg were utilised for raids on the Midlands and Portsmouth.[48]

Aircrews of WIDU continued to carry out the important task of monitoring the effectiveness of RAF jamming signals. Taking off while German air raids against targets located in the United Kingdom were either imminent or actually in progress, they found that sometimes jamming frequencies did not match exactly those of the beams, and were inclined to wander. In these circumstances German aircrews could receive Knickebein signals at great ranges, even as far as the Orkneys on one occasion, clearly and without interruption and thus make full use of them for their intended purpose of accurate navigation and bombing.[49] Where, however, the frequencies were identical, the German beam was blotted out in the vicinity of the Jammer's location. In order to rectify this fault, the RAF jamming transmitters were modified by introducing crystal control of the frequencies in use.[50] Not surprisingly the crews of WIDU were kept extremely busy at this time for, as new or modified jammers were introduced, it obviously became necessary to check and report on their effectiveness.

This was obviously also the case with the Deviator system. This device was invariably used whenever the Kleves Knickebein was operating, it being ascertained that, while there was no evidence of a shift of the beam, the equi-signal was being masked. In view of these results and the difficulties involved in the installation of such equipment on a large scale, it was decided to abandon the idea of synchronised jamming and concentrate

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[48] PRO Air 41/46, p.6.

[49] Michael Cumming, *Beam Bombers*, p.20.

[50] PRO Air 41/46, p.6.

instead on the easier and more effective unsynchronised methods. It now became apparent that in order to ensure complete jamming coverage of the whole of the United Kingdom, a greater concentration of transmitters with higher power was required. Perhaps of equal importance was the need to increase the number of ground listening stations on the South coast, in order to monitor the transmissions of the newly installed Knickebein stations in Northern France, which had recently become active.[51] To identify German radio aids and to ascertain the effectiveness of RAF Countermeasures it was necessary, more than ever, to conduct investigative flights.[52] Self-monitoring of Aspirin stations also became more important.[53] As previously explained, unless the jamming frequency matched that of the German signal as closely as possible, then the countermeasure could be rendered useless. It also became necessary to observe and react to alterations of German beam characteristics quickly, as this could possibly signify changes to beam settings and thus a change of target. As a preliminary measure, each jamming station was allocated a suitable radio receiver in order to fulfil these tasks. This was done as promptly as possible: to expedite the process, jammers were switched off by arrangement for ten minutes, thus allowing reception and calibration of appropriate German signals. It was quickly realised, however, that Luftwaffe aircrews could obtain considerable advantage from this policy, since it enabled them to check their positions during the jamming-free period. Consequently, the period was reduced to five minutes and, later,

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[51] Ibid.

[52] PRO Air 26/580, p.1.

[53] PRO Air 41/46, pp.11-12.

phased out completely, when specialised monitoring stations were introduced, complete with directional aerials.[54]

The Aspirin jammers, which had been ordered earlier against Knickebein, started to become available from the beginning of September 1940. They were sited to protect the main industrial centres and the East and South Coasts, which included the ports and hinterland. Soon evidence began to accumulate that the Luftwaffe was experiencing problems with Knickebein.[55] On the night of 24 September 1940, during the fourth and penultimate phase of the Battle of Britain, the Luftwaffe intended to attack Rochester and the Thameshaven oil tanks. The Y-Service, however, intercepted an interchange of frequencies between two Knickebein stations, intended to avoid the effect of Aspirin. Clearly this countermeasure was having an effect. The end result of the attack was that the bombs actually fell on London and not on the selected targets.[56] Later, statements made by captured German aircrew indicated that Knickebein used over the United Kingdom for navigation and bombing purposes was generally unreliable. One such account, which referred to the September period, pointed out that it was known in Germany that the beams were being interfered with.[57] Even so, it took a lot of persuasion for the Luftwaffe technical staff to be convinced of the veracity of this information.[58] They were certain that any difficulties experienced by their aircrew were purely local, and advised pilots to continue to

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[54] PRO Air 41/46, pp.11-12.

[55] Ibid.

[56] Derek Wood, *The Narrow Margin*, p.229.

[57] PRO Air 41/46, pp.11-12; Ken Wakefield, *Pfadfinder*, p.55.

[58] Ibid.

fly on course as briefed, when eventually they would pick up the relevant beam or beams. Such advice by the signals staff to experienced aircrew personnel was not well received.[59]

By January 1941 it was apparent that the German scientific experts were at last beginning to believe their pilots' reports that Knickebein over this country was unreliable.

> An interesting report was received describing a lecture given by an engineer to a number of experienced German pilots. The pilots were told that the area of disturbance of the beams was purely local so that if, on reaching the disturbed area, they continued on their course, they would eventually pick up the beam. The report concluded by stating that the audience did not seem to be at all impressed by the advice given to them.[60]

In view of German faith in their operations security, this attitude on the part of the engineer was understandable. A subsequent RAF investigative flight carried out, at height, with an aircraft fitted with an appropriate captured German radio, confirmed that Knickebein had been thoroughly jammed throughout its length, except during the shut-down period already mentioned. It was also thought probable that, in order to counter RAF action, the Luftwaffe would start to use other frequencies for Knickebein, or change the audio modulation frequency or even introduce frequency modulation.[61] The most likely step was

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[59] Ibid.

[60] A.I.1(K) Report No 31/41, quoted in PRO Air 41/46, p.11.

[61] PRO Air 41/46, pp.11-12.

considered to be the first, as this would involve the least modification to existing equipment. Fortunately for the British, the higher-powered RAF transmitters, already mentioned, would be able to overcome this particular move. As a precaution, however, the smaller jammers were also modified in order to accommodate frequency changes in the band and audio modulation frequency. To overcome the third, and least likely measure, RAF equipment was modified to include an item known as a 'Wobulator'. The Luftwaffe then realised that by switching on Knickebein early they were disclosing important information prematurely; this sometimes happened when air and ground crews were being trained and during the alignment procedure. Consequently, the length of time the beams were transmitted prior to an attack was progressively reduced until there came a period when they became available for use only after German aircraft had actually crossed the coastline of the United Kingdom. This action caused renewed difficulties for the RCM organisation in general and No 80 Wing in particular; as a result of it, RAF personnel involved with radio countermeasures were required to react more quickly and just as accurately as hitherto.[62]

7. Elektra and Meaconing

The existence of the German Elektra system of radio navigation had first became known in August 1940. It was of unusual design, consisting of a fan of equi-signal beams spaced 5 degrees apart and separated by alternate dot and dash sectors, which covered the whole of the United Kingdom. The transmitter appeared to be located near Bredstedt, but its actual site was later confirmed to be at St Peters, near Husum in Schleswig. Tests

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[62] Ibid., 41/46, p.12.

disclosed a beam pattern on a Medium Frequency of 481 Kilocycles. The signals were keyed at the Knickebein rate of 60 per minute, although the transmissions were unmodulated. Elektra was believed to be used as a long distant navigation aid by Luftwaffe aircraft shadowing or attacking convoys at ranges of up to 1500 miles. It could also be employed in conjunction with Knickebein. It was dealt with by Meacon equipment in the same way as the other beacons.[63]

8. German Avoidance of Meaconing

The Luftwaffe possessed a first class safety service for its aircrew in distress. This comprised a network of high-grade Direction Finding stations operating in the 150-600 Kcs bands. The system was extended during 1940 to enable German aircraft flying over the United Kingdom, or the Western Approaches, to call for assistance if required.[64] As the RAF Meacon countermeasures became successful against other navigation aids, a new use was found for the Safety Service. It started to provide position information to German aircrews engaged in active air operations while over the United Kingdom. Fortunately for the British, sensitive Meacon equipment had been designed in advance. But there was a snag: Aircraft Meaconing (ACM) operators had to be highly skilled in Meaconing signals of varying frequency, strength and short duration.[65] However, with well-trained operators, and the help of the Royal Air Force Y-Service, ACM proved to be a successful countermeasure to the Safety Service transmitters. So much was this the case that the Luftwaffe resorted to adopting

[63] PRO Air 41/46, p.23 and App.“ L”; PRO Air 20/8953, p.16.

[64] PRO Air 41/46, App.“C”, pp.9-10.

[65] Ibid.

alternative frequencies until August 1942, after which date German aircrew generally used the Safety Service only while over the Continent.[66] Occasionally, crews attempted to use this service when flying over the United Kingdom, but the ACM site operators usually dealt with these incursions as they arose.[67] (See Figure 8)

9. Ruffians and Bromides

A new type of signal having beam characteristics on 74 Mcs. was first heard on the Kent coast in August 1940.[68] Unknown to the British authorities, this was the device first used operationally by the Luftwaffe operationally during the Polish campaign. Initial reports were treated circumspectly, especially as no known German radio could receive this frequency. Later, further signals of this nature were received, and confirmed, by RAF ground Direction Finding stations and airborne investigation. Their origin appeared to lie in the area of Calais, Le Havre and Cherbourg. The beams differed from Knickebein in such detail as radio frequency, modulation frequency, and rate of keying. The principle employed was reminiscent of a navigation aid for either shipping or aircraft. Evidence began to accumulate about the new beams and by September 1940 a lot more was known about them.

> The cryptographers had broken a new line of Enigma traffic. There were mention of beams, including one which said that the beam width was eight to ten seconds of arc, or an angle of one in twenty thousand, which would imply that the beam was no wider than

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[66] PRO Avia 7/407.

[67] PRO Air 41/46, p.24 & App."C".

[68] PRO Avia 7/779; PRO Air 26/580.

AIR 41/46

Figure 8

GAF Safety Service Ground Control Stations
& RAF ACM Transmitters

> twenty yards at two hundred miles. And there was the electrifying word X-Gerät…[69]

It subsequently transpired that this new, and technically advanced system, was known as X-Verfahren and it was designed as a precise blind-bombing aid, with a delivery accuracy of between 10-20 yards, when the aircraft involved was operating over London.[70] Fine and coarse approach, and crossbeams were employed. Scientific Air Intelligence deduced how X-Verfahren worked and concluded that if it was as accurate as forecast, then it could become an even greater threat to the United Kingdom than Knickebein.[71] A countermeasure against this new device, allocated the code name Ruffian, was quickly put in hand, but finding a transmitter in the 65-75 Mcs frequency band at this particular time in the United Kingdom was not an easy task. By accident, an Army Gun Laying Pulse transmitter Type GL/T MK1 was found suitable, if converted firstly to a pulsing jammer, and later a continuous wave transmitter complete with grid modulation.[72] The Royal Navy also helped when its Signal School, at short notice, provided an emergency transmitter with alternative audio modulation frequencies. The transmitters used against X-Verfahren beams under this particular countermeasure were given the code name Bromide.[73] One of each type was in operation during the first week in November; the modified Army GL set was installed at Hagley, near Birmingham, and the Royal Navy

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[69] R.V.Jones, *Most Secret War*, p.135.

[70] Laurie Brettingham, *Beam Benders, Royal Air Force 80 (Signals) Wing 1940-1945*, p.19.

[71] PRO Air 20/1627.

[72] PRO Air 26/580, Organisation and Functions of No 80 Wing.

[73] PRO Air 41/46, p.14.

transmitter on high ground at Birdlip in Gloucestershire. These equipments were carefully sited to cover the approach beams emanating from Cherbourg on 66.5 to 71.1 Mcs which, when switched on, were aligned to assist German aircraft attacking targets situated in the Midlands, an area which had recently been subject to air attack by aircraft using this system. Even so, at this stage, no great hopes were pinned on these measures because of the small number of Bromides available, the manifold frequencies employed simultaneously by the Luftwaffe and the great skill, speed and precision required of the RAF and WAAF operators of this equipment. Moreover, monitoring of the jamming signal proved to be particularly difficult.[74]

It had not been expected however that in the early stage the jammers would have any marked effect owing to the number of frequencies used simultaneously in this system and the limited number of jammers available. Also, the personnel available for operating the jammers were comparatively unskilled in the handling of the complicated equipment with the precision and speed necessary for its efficient use. The monitoring of the jammers to ensure that these were on the exact frequency of the enemy signal also proved to be a difficult problem.[75] In mid-November an aircraft of KGr 100, the Luftwaffe Pathfinder unit known to use X-Gerät equipment, crashed on the beach near Bridport as a result of Meaconing action by No 80 Wing. Much information about the system was obtained from the crew and, although the aircraft itself could not be salvaged, due to a dispute between the Royal Navy and British Army, valuable items such as receivers and the all-

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[74] Ibid.

[75] Ibid.

important clock used for computing ground speed were recovered. (See Figure 9). Narrow band audio filters were found in the receiver circuits designed to operate on a frequency of 2 Kcs with a tolerance of plus or minus 50 cps.[76] As a result of this information the audio modulation of the Bromide transmitters had to be modified and a close watch maintained for drift in order to ensure that the jamming signal remained effective. The X-Gerät, together with its Ruffian system of beams, produced an accurate method of bombing targets in the dark or in poor weather conditions. Up to seven beams could be employed at any one time with a different frequency. Coarse approach and cross beams, of about 4 degrees, in some of which fine beams of 0.05 degrees were inset were employed. In setting up an X-Gerät attack, the German crew involved would first use dead reckoning navigation when flying the aircraft to the general area of the target.[77]

> The two radio receivers installed in the aircraft would then be tuned to the coarse approach, and cross beams, respectively. At a point 'O', the aircraft would enter the area of the coarse cross beam when the pilot would align the aircraft with the direction of the coarse approach beam. At this juncture, the wireless operator would re-tune the pilot's receiver to the frequency of the fine approach beam, along which the aircraft would be flown towards the target at a constant height and speed. The wireless operator would then retune the observer's receiver to the frequency of the first fine crossbeam. Meanwhile, the observer would depress the

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[76] PRO Air 41/46 App.“H”.

[77] PRO Air 20/1627.

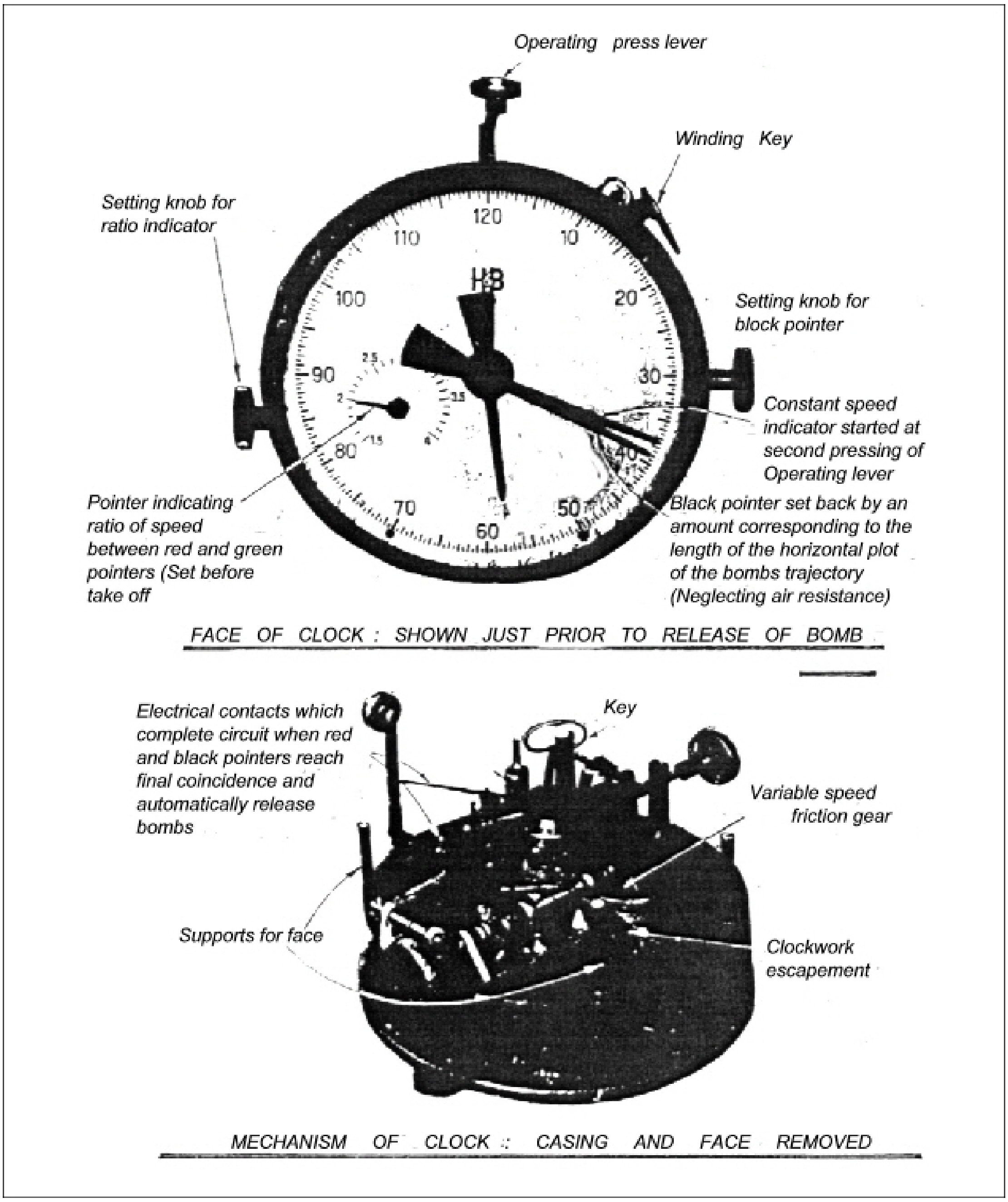

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Figure 9

X – Gerät Clock

> key on the clock as the aircraft reached a point 'P'. The observer's receiver would then be retuned to the frequency of the second fine cross beam, and, when a point 'Q' was reached, the observer would press the clock key a second time. The ground speed of the aircraft was now automatically computed and, provided the correct height, and speed had been maintained, the bombs would be released electrically at a point 'R' to hit the target at point 'X'.[78]

Meanwhile, the installation of the new British Bromide transmitters continued, while ground and air receiving stations monitored the German Ruffian or X–Verfahren beam signals. The air commitment was carried out by the aircrew of WIDU, in Ansons and Whitley aircraft on a regular basis, and often in appalling weather conditions. The information so obtained in the Cherbourg area, about beam alignments, width and frequencies, proved to be invaluable to No 80 Wing. In view of the seriousness of the situation, including the threat posed by X-Verfahren to the United Kingdom, it was decided to take offensive action against the Ruffian transmitters. Preliminary trials seemed to offer some hope to the British and, accordingly, a series of attacks began on 12 November.[79] During one of the Luftwaffe's heaviest raids on Coventry, on 14 November, a sortie was undertaken against the transmitters in the Cherbourg area by two aircraft of WIDU. The smallness of the target made it difficult to damage, especially at night; but nevertheless at least one of the targets received a direct

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[78] PRO Air 41/46 App.“H”.

[79] PRO Air 26/580.

hit and the attacks continued.[80] The main objectives of this action were the Ruffians sited in the Cherbourg peninsula. Later on, however, attacks were also attempted against other transmitters located at Morlaix, north east of Brest. The experience gained from these sorties led to the devising of more accurate methods of determining the target which, in turn, led to experiments in the use of luminous marker bombs and the development of a narrow beam for navigation and bombing purposes, named Oboe.

In order to obtain warning of attack, as early as possible, listening stations, some of them mobile, were positioned in the Bournemouth area, over which the Cherbourg approach beams passed. On the night of the raid against Coventry, 14-15 November, there was a problem that the Bromide jammers, although set to the correct frequencies, used a note modulated at 1500 Kcs when it should have been 2000 Kcs. The upshot was that the Bromides were ineffective on this occasion, against an attack spearheaded by KGr 100 using the recently introduced fire-lighting or incendiary tactics.[81] It also proved to be difficult to distinguish between the Ruffian's main beam and the large number of associated subsidiary beams, as indeed occurred on the night of 24 November 1940. On this occasion the main beam was directed towards Bristol, with a subsidiary one covering the Bournemouth area. This gave rise to the possibility of Coventry being the target again. By the end of 1940 an analysis of the Ruffian beams, in which WIDU played a prominent part, enabled a beam predictor to be devised. It was not as straightforward as the one used for Knickebein, as it had to cope with the numerous beams employed:

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[80] PRO Air 41/46, pp.17-19.

[81] PRO Air 8/352; Ken Wakefield, *Pfadfinder*, pp.77-78.

basically five beams were used, sometimes with the help of seven transmitters; any additional fine beams so generated being used in the event of jamming or electrical failure. They were distributed as follows: Approach – 1 coarse, 2 fine (frequency band 66.5-71.1Mcs) and Cross – 1 coarse, 3 fine (frequency band 71.5-75Mcs). [82]

In view of the growing importance of WIDU and the tasks it was undertaking, the Air Ministry decided to raise it to the status of a full squadron and consequently, on 10 December 1940, it became No 109 squadron.[83] Two additional Ruffian transmitters were added to the Luftwaffe inventory in January 1941, becoming operational in the Morlaix area between Cherbourg and Brest. These beams were used to assist Luftwaffe pathfinder aircraft approach and bomb targets situated in the West Country and South Wales, the associated crossbeams coming from Cherbourg.[84] The first batch of seventeen new Bromides was shortly, and successfully, installed at widely spaced locations in the United Kingdom. The Germans noticed this increase in jamming resources and the improvement in operating standards, and they took appropriate action. Beams were no longer aligned with targets in the United Kingdom prior to a raid or, if they were, the frequencies employed were changed before the actual attack took place. The Luftwaffe transmitted multiple beams, all simultaneously, and often not all of these were required. This made the task of selecting the correct letter on selected beams to be used on any one night a complicated one. To assist their crews the German Air Force took to superimposing, at regular intervals, a single Morse letter while

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[82] PRO Air 41/46, pp.15-16.

[83] Michael Cumming, *Beam Bombers*, p.19.

[84] PRO Air 41/46, p.14.

operations were actually in progress. Although this was changed, along with frequencies, at different times it was still possible for the RAF to identify individual transmitters.[85]

On 6 October 1940, Enigma provided Scientific Air Intelligence with a copy of an intercepted signal addressed to a single Wotan II or Benito station located northwest of Cherbourg, giving details of a target located in the United Kingdom.[86] Some days later the army base at Bovingdon was attacked, and soon the listening service reported hearing beams operating between 40 Mcs and 50 Mcs. Such a beam-cum-ranging system had been predicted and may well have been hinted at in the remarkable Oslo Report received in 1939. The following November, further signals were heard by the listening stations in the 40 Mcs band.[87] Similar investigations were then carried out as for the earlier type beam transmissions, with the result that the associated keying rate was found to be high, at some 180 per minute a far higher rate than either the Knickebein or Ruffian signals.[88] The new beam appeared to have originated in the Cassel area in Northern France, where a second transmitter was located. A third site for this beam was also found in the Poix area. This information, together with later Y-Service intelligence, reinforced the view that the Luftwaffe was developing a new bombing aid, which, somewhat unusually, employed a single beam.[89] Benito comprised two different and distinct parts, namely Benito range or distance measurement, and the Benito beam. With

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[85] PRO Air 41/46, p.17.

[86] PRO Avia 26/438.

[87] PRO Air 41/46, pp.20-21.

[88] PRO Air 20/1624; PRO Air 20/1626; PRO Air 20/1627; PRO Air 40/2242.

[89] PRO Air 41/46, p.21 and App.“K”.

this system, which had already been used operationally, it transpired that distance measurements along the beam were obtained by measuring the phase angle between the outgoing and incoming modulations.[90] For the moment, however, the precise working of Benito continued to elude Scientific Air intelligence, TRE and the Royal Aircraft Establishment (RAE), where captured German aircraft and their equipment were examined. (See Figure 10)

10. Colonel Turner's Department and Starfish

Activities conducted under the cloak of the codename Starfish were closely connected with the work of HQ No 80 Wing and its associated Operations Room. Briefly, Starfish referred to decoy fires and all the measures necessary to support and maintain such an organisation. Because the effects of radio countermeasures could be offset, to some extent, by the visual advantage obtained from large fires burning on the ground at night, a number of decoy fires were prepared in advance and set in open country adjacent to likely targets. Critical to the success of the scheme was the time of lighting; HQ 80 Wing was judged to be in the best position to come to this decision. The first Starfish site came into operation during an attack on Bristol on 2-3 December 1940, when the two sites fired collected a total of 66 H.E. bombs. Thereafter, Starfish played an important part in the defensive campaign, sometimes attracting as much as 75 per cent of the total German effort.[91] Evidence obtained from German Air Force prisoners of war showed that, although in many cases they were aware of the existence of decoy fires, their ideas about the composition and location of the fires

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[90] PRO Air 41/46, p.20.

[91] PRO Air 41/46, pp.24-26.

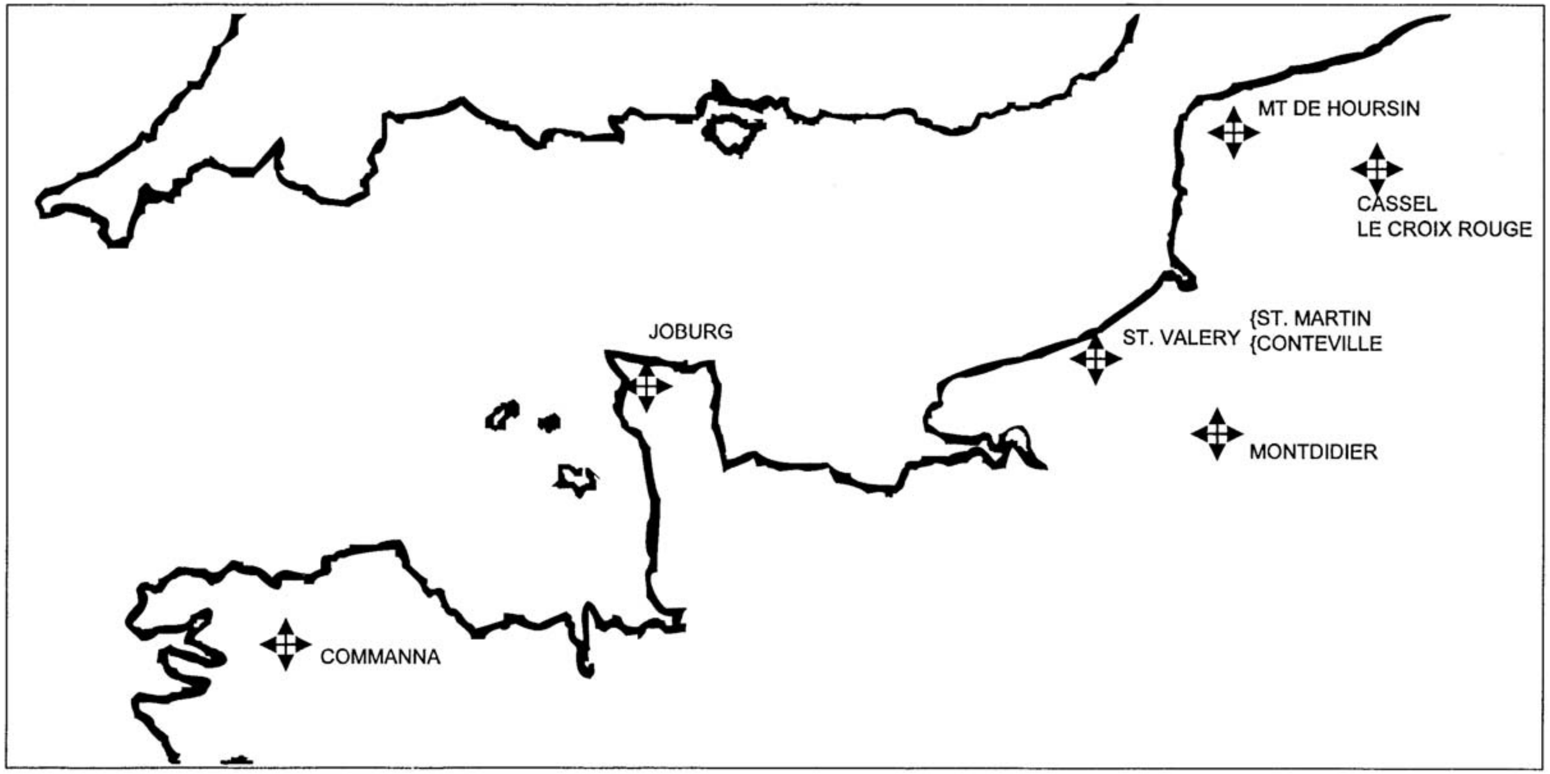

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Figure 10

Positions of known Benito Stations

were totally erroneous. The Starfish organisation was the responsibility of Colonel Turner and the Department of the Air Ministry, named after him.[92]

Summary

In March 1939, unknown to the Royal Air Force, selected crews of the Luftwaffe were already receiving training in the use of X-Verfahren, thus making it the most advanced air force in the world in navigation and bombing techniques.[93] Indeed, after the outbreak of hostilities the opportunity was taken to hold trials of X-Gerät and Knickebein equipments over France and the East Coast of Britain. In spite of warnings received in London, the German invasion of Denmark and Norway in April 1940 achieved complete surprise; this was followed a month later by an assault in the West, employing Blitzkrieg tactics against the allies for the very first time. Belgium, Holland, Luxembourg and France soon fell to the advancing German forces, with the result that most of the British Expeditionary Force was forced to retreat to Dunkirk, prior to an evacuation by sea. Soon afterwards from intelligence and Enigma information, it was surmised that not only were the Germans capable of producing radar, but also radio beams for navigation and blind-bombing purposes. The Luftwaffe also favoured the use of Medium Frequency radio beacons for navigation purposes; in response action was quickly taken to nullify the use of these latter aids with a device called Meacon. In order to use this equipment successfully, a high standard of

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[92] Ibid.

[93] Some intelligence about the strength of the German Air Force was available from 1934, but little was known about X-Verfahren. F.H. Hinsley, *British Intelligence in the Second World War*, vol.1, p.53.

operating was required from the RAF personnel involved, together with prior knowledge of current Luftwaffe call signs and frequencies. The Y (listening) Service provided much of the essential information.

From the detailed analysis subsequently made of Knickebein beam signals conducted by No 80 (Signals) Wing, it was found possible, with the aid of a theoretical diagram, to predict the setting of the main beam prior to the actual attack, and hence the target. When an actual Knickebein document fell into RAF hands in July 1940, the theoretical diagram compared favourably with the original version. This information was warmly welcomed at HQ Fighter Command as it enabled air and ground defences to be strengthened in advance as deemed appropriate. At this time information was received from Enigma about two new Knickebein sites in France, and another in Stavangar, in Norway. However, without the continuous support of WIDU, later No 109 Squadron, No 80 (Signals) Wing would have been hard put to confirm the location of the new German sites and to check on the efficacy of their own jamming transmitters. Indeed such assistance undoubtedly led, indirectly, to the introduction of crystal control. In addition, the air unit contributed valuable intelligence on the German beam transmitters, confirming especially the width of the beam being employed and the frequencies in use.

Because it was vital that all jamming undertaken by No 80 Wing was accurate, it was considered expedient for Aspirin stations to be provided with equipment which would enable them to conduct their own monitoring. Thus they became self-monitoring Aspirin stations. By 24 September 1940, it was confirmed that Aspirin was an effective antidote against Knickebein, making use of the beam for navigation and bombing purposes by Luftwaffe aircrews difficult. The Luftwaffe recognised this interference and started to reduce the time during which beams were transmitted, especially prior to a raid. Another navigation device, Elektra, the existence of which had become known in August 1940, was dealt with in the same way as other beacons, and just as effectively by Meaconing.

In August, too, a new signal was heard on 74 Mcs for the first time in the United Kingdom. This was X-Verfahren. These Ruffian signals were confirmed by WIDU and ground monitors, as originating in the Calais, Le Havre and Cherbourg areas of France. Difficulty was experienced in finding a suitable jamming device covering this frequency at the time, but it was found that certain Army and Navy transmitters could be used for the purpose, if suitably modified. One of each was deployed to cover the Midlands in November 1940, under the codename Bromide. Not too much was expected from these equipments, however, in view of the small numbers available, the frequencies to be covered, and the difficulties involved in monitoring the signals. The British enjoyed a piece of good luck when the He 111, which crashed in Dorset in the middle of the month, provided much more information about X-Verfahren than was known hitherto. This new information helped Scientific Air Intelligence and RAE Farnborough to deduce how the system operated, enabling improvements to be made to later Bromides. Further jammers were then deployed, but X-Verfahren was now considered to be such a threat to the United Kingdom that air attacks against the transmitters were contemplated. Indeed, a singular series of such sorties was initiated on 12 November 1940 and, two days later, the night of the devastating Luftwaffe raid on Coventry, two Whitley aircraft of WIDU flew down the German beam and bombed its origin, with the result that at least one of the transmitters was silenced for a time. While the RAF was taking action against Knickebein and X-Verfahren, Enigma had provided information, the previous month, about the third German beam, Benito, or Wotan II. A day or so later the British Army base at Bovingdon was attacked with the aid of this device. The new beams originated from the Cassel and Poix areas of France and operated on frequencies between 40-50 Mcs. Unfortunately for the Radio Countermeasure (RCM) organisation, little more was known at the time about the new system other than that it employed a single beam and was more accurate than either of the previous two devices. In this chapter an explanation has been provided as to how the Luftwaffe's beacons and beams came to be found and, having analysed the difficulties which had to be overcome in the early months, we will now look in detail at No 80 (Signals) Wing, its operations and organisation.

CHAPTER THREE: NO 80 WING, RCM BOARD AND TRE

1. No 80 (Signals) Wing, Organisation and Operations

When No 80 Wing was first formed under the command of a signal specialist, the recently promoted Group Captain E.B. Addison, Royal Air Force, it was allocated the following limited responsibilities:

> To Meacon enemy medium frequency wireless beacons used by the German Air Force as an aid to air navigation while operating over or near the United Kingdom. To jam enemy VHF Knickebein beams on 30 and 31.5 Mcs being used for all-weather area bombing.[1]

As we have seen, jamming and Meaconing started on an ad hoc basis in June and July of 1940, the scale of countermeasures increasing from the date when the Wing was first formed at Garston in the following August. Countermeasures commenced on a regular basis on 20 August.[2] From the experience so gained it quickly became obvious to Addison and his small staff that, in order to carry out the given commitment, a minimum requirement would be a central operations room, together with the necessary communications to and from the various listening and jamming sites. Consequently, more suitable accommodation was found at Aldenham Lodge at Radlett in Hertfordshire. From October, 1940, staff of Headquarters No 80 Wing were employed as follows: a Commanding Officer, a Duty Wing Commander made up from Wing Commanders C.S. Cadell and Fitch and Squadron Leader Hebden,

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[1] Unpublished History of No 80 Wing, App.“D”, p.1, PRO, Air 41/46.

[2] No 80 Wing Operations Record Book, Form 540, p.3, PRO Air 26/580.

a Scientific Analyst, Mr R.I. Wells, who was assisted by Flight Lieutenant Baillie from WIDU, a duty Operations Officer who had under him a Meacon Control Officer and a Headache Control Officer, together with about eight Special Duty Clerks.[3] The duty Wing Commander was placed in charge of all operations throughout his particular watch period. He was assisted by the Operations Officer who had been made responsible for the general organisation and for supervising the work of the operations room personnel as a whole, thus ensuring that the various sections worked together as a team. In addition to obtaining information from HQ Fighter Command (HQFC) about the current air situation, other duties which fell to the Operations Officer included passing details of German beam settings, when these became known, to the staff of interested formations such as HQFC (duty Air Commodore) and to the Air Ministry (duty Group Captain).

The Headache Control section ensured that, when ordered, all appropriate Aspirin jammers were switched on and continuously operated on the correct frequencies throughout the hours of darkness. By 25 October 1940 this involved passing instructions to some fifteen Lorenz type Aspirin sites, in particular to Ide Hill, where a modified SWB8B transmitter giving eight hundred watts of aerial power was located; the only exception to the continuous operation was the three or four pre-arranged breaks of ten minutes duration already mentioned.[4] As we have seen, these listening periods enabled the airmen and airwomen manning the jamming sites furnished with receivers and personnel at the special listening

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[3] PRO Air 26/580, p.4.

[4] PRO Air 41/46, pp.6, 9-10; F.H. Hinsley, *British Intelligence in the Second World War,* vol.1, p.325.

sites to monitor for German signals active in the 30 and 31.5 Mcs bands.[5] Because of demand at this stage of the war, HQ 80 Wing had been unable to secure its own dedicated telephone lines for this aspect of its work. Hence the monitoring results had to be passed to Headache Control via the public telephone network or PTN. An improvement, however, occurred in telephonic communications in February, 1941 when trunk sub-lines to main Watcher sites were left permanently connected and voice-operated relays (VOR) were installed. Reports were thus received more quickly, and instructions, for example, to change Bromide transmitter frequencies, accelerated. The clerks received this information which was promptly logged and subsequently analysed in detail. As the messages were received a coloured pin, representing the characteristic heard, was inserted in the appropriate map reference of the reporting site. Thus it was possible to ascertain at a glance which Knickebein were active and to confirm the direction in which the beams were set. New maps were prepared as further Knickebein frequencies were intercepted and came into operation. The work of this particular section was not yet over, however, as coloured chords now had to be positioned on a further map in order to see if any of the beams intersected over a potential target. It was also convenient to plot on these Aspirin maps the continental Knickebein sites together with the frequencies employed. In this way, whenever a beam was swung on to an alternative target, gaps in the jamming defences became evident, thereby expediting any necessary remedial action.[6]

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[5] PRO Air 41/46 App."D", p.1.

[6] Ibid., p.2.

The importance to the radio countermeasure organisation of following these procedures quickly and efficiently requires little emphasis. Significantly, the Headache Control Officer was also given the task of initiating action whenever an investigative flight had to be undertaken by No 109 Squadron. After such a sortie had been completed, the crew would be de-briefed over a telephone tie line from HQ 80 Wing and a preliminary report given to the Duty Wing Commander and Scientific Analyst.[7] From mid-August, the Luftwaffe had started to employ X-Verfahren beams on the VHF frequencies of 66.5 and 75 Mcs.[8] Fortunately, this sort of development had been foreseen and consequently suitable receivers had been pre-positioned at selected listening sites, where a continuous monitoring watch was maintained. Instead of forming a separate Ruffian section at this juncture, however, Ruffian signals were reported to Headache Control for logging action and future analysis. But this was about all.

Countermeasures were not yet available although much of No 109 Squadron's current work was concerned with this particular threat. It is of interest to note that when the Air Ministry issued a chronology to mark the 50th Anniversary of the RAF, the first use of Bromide transmitters against the Ruffians is cited as being on the 5th September 1940.[9] In contrast, No 80 Wing recorded that the first two jammers were not brought into operation until early in November.[10] From the description of his duties and responsibilities, it is evident that the Headache Control

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[7] PRO Air 26/580, p.5.

[8] PRO Air 20/1627; R.V. Jones, *Most Secret War*, p.137.

[9] DPR (RAF), Chronology 50th Anniversary of the Royal Air Force, p.16.

[10] PRO Air 41/46, p.14.

Officer's task was no sinecure; indeed he played a key role in the work of the Operations Room. The other section was concerned with Meaconing and there the Control Officer was responsible for all radio countermeasures taken against the German Medium Frequency beacons. Essential and timely information to enable this action to be undertaken successfully was forthcoming from Royal Air Force Cheadle, a major source of Y intelligence gleaned, in this instance, mainly from German W/T transmissions.[11] Communication between 80 Wing and Cheadle was generally by telephone tie line, which had been specially installed for the purpose.

A feature of the successful German Air Force's M/F beacon system was the planned interchange of call signs and frequencies. Obviously, when these occurred, and before Meaconing could begin, the precise location of the origin of each German call sign had to be located with the assistance of RAF Direction Finding stations. This information was then quickly passed to Meacon Control, where it was carefully logged for future use. (See Figure 10A for No 80 Wing's Watcher and Jamming sites) A beacon activity sheet was then raised which contained provision for planning future countermeasures.[12] For convenience, reported beam activity and RAF countermeasures were displayed on a map showing the location of each Meacon station, together with its rejection angle and reference letter. (See Figure 10A for No 80 Wing's sites). Individual Meacon transmitters were then numbered and thus, for example, the Flimwell complex in Kent and its four

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[11] PRO Air 41/46 App.“D”, p.8.

[12] Ibid., p.2.

AIR 26/580

Figure 10A
No. 80 Wing Sites

transmitters were labelled A1 to A4. Active German beacons were also marked on the same map. When the Meacon Control Officer decided to jam a specific beacon, the personnel at the site selected to carry out the actual work had to be informed of the Luftwaffe callsign, and precise frequency and letter and number of the RAF transmitter being employed. In order to facilitate the allocation of jammers to beacons, a list was displayed of the relative power, and hence the range, of all available Meacon transmitters at each site.[13] The reference pin of the transmitter so selected was then removed and inserted at the map reference of the Luftwaffe beacon.[14] (See Figure 11)

The Meacon Control Officer needed to know the current air situation over the United Kingdom and this information was furnished by 80 Wing's excellent liaison section at Headquarters Fighter Command. Such intelligence included the routes adopted by Luftwaffe aircraft approaching, or likely to approach, targets situated in the United Kingdom, taking into consideration any existing Knickebein settings. Aware of this information the staff concerned found it easier, when selecting a Meacon site for jamming purposes, to avoid choosing one located directly on a track linking beacon to target. Because of the limited number of transmitters available, it was necessary to concentrate the available resources on those German beacons which, at the time, seemed most likely to be used by the crews of GAF aircraft. No 80 Wing enjoyed a pre-eminent position in the realm of RCM, having been allocated the highest of priorities for the acquisition of personnel and equipment, a condition insisted upon by Addison

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[13] PRO Air 41/46 App.“D”, p.3.

[14] Ibid.

TRANSMITTERS AVAILABLE																	
R	MINT'LW	RESTON	MARSKE	LOUTH	MUN'SLY	SCOLE	B'TREE	HP'DEN	W'SHAM	FLIM'L	HEN'FD	ROGATE	NEW'B'Y	LYMP'SM	T'COMBE	F'MILE	
12	M 11	M 11	SONNE1	M24	SONNE5	TFM1$_A$	TFM1$_A$	A 1111	TFM1$_A$	TFM1$_A$	A 11 H	M 24	TFM1$_A$	M 24	M 11	TFM1$_A$	12
13	G 12$_A$	STAVANG'R	G 12$_A$	M 11	G 12$_A$	G 12$_E$	G 12$_E$	R.C.A.	G 12$_A$	M11	G 12$_E$	G 12$_B$	M11	G 12$_E$	G 12$_E$	M 24	13
14	T 77$_B$	T 77	R.C.A.	R.C.A.	R.C.A.	R.C.A.	R.C.A.	TFM 2	R.C.A.	R.C.A.	TFM2		R.C.A.	R.C.A.	G 12$_A$	G 12$_A$	14
15	T 77			T 77	T 77$_B$	T 77	T 77	T 77$_A$	T 77	T 77$_A$	T 77	TFM2	T 77	T 77$_B$	TFM2	TFM2	15
16 ACM		T 77	384	416				T 77$_B$	T 77					T 77$_A$		T77	16 ACM
17 ACM			T 1087		1087				1087		1087					T 1087	17 ACM
18 ACM	G 12$_F$	G 12$_F$	G 12$_F$	G 12$_F$										G 12$_F$	G 12$_F$		18 ACM

BEACON ACTIVITY

SONNE1	STAVANG	SONNE 5				GRIS NEZ	FECAMP									

BOARD:- MARKED OUT IN WHITE ON BLACK WITH
NAMES OF TRANSMITTERS IN YELLOW
PLAQUES:- WHITE ON BLACK DENOTING 'BEACON COVERED'
REVERSE SIDE BLACK ON WHITE DENOTING 'TRANSMITTER ORDERED TO RADIATE'

AIR 41/46

Figure 11
Meacon Display Board

before taking up an appointment which involved working in such an important and highly sensitive field.[15]

Personnel were a problem in that electronic warfare was a totally new field and needed first-class minds to make it work. Fortunately the Wing's work was considered so important that it was given carte blanche in its search for men and materials.[16] There were difficulties as, for example, with the telephone lines. Moreover, controllers sometimes had their proposed countermeasures countermanded by the staff at Headquarters Bomber Command, situated at High Wycombe.[17] This came about when crews of RAF aircraft wished to employ German beacons for their own navigation purposes, the relevant information being received at Radlett each evening prior to bomber operations taking place. Appropriate instructions were then displayed in a prominent position in Meacon Control. By the end of October 1940, with the successful conclusion of the Battle of Britain, albeit by the narrowest of margins, and with considerable help from radar, it became possible to jam the Ruffian beams on a regular basis, with the aid of the newly arrived Bromide transmitters. However, not all the details were known about X-Verfahren, as demonstrated at Coventry on the night 14-15 November 1940.[18] By now, the heavy losses sustained by day had forced the German Air Force to turn to the night bombing of London and other British cities and towns. Accordingly, No 80 Wing's activities expanded over the next few months in which the mobile watcher sites, operating along the

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[15] Martin Streetly, *Confound and Destroy*, pp.14-15.

[16] Ibid.

[17] PRO Air 41/46 App.“D”, p.3; PRO Air 41/46, p.8.

[18] F.H Hinsley, *British Intelligence in World War Two*, vol.1, pp.325-326.

south coast of England, played an important and integral part. Personnel at these locations were able to pinpoint quickly and accurately the positions at which Ruffian beams from Cherbourg crossed the coast.[19] Generally, Bromide transmitters were positioned in order to protect major target areas while a smaller number of the higher-powered variety, complete with rotating aerials, concentrated on the intersection of German beams. It was now that the Glowworm decoy fire organisation – later known as Starfish – became operational and placed under the control of HQ No 80 Wing. But this was not the end of the increase in commitments. Benito, the Germans' single blind bombing beam, which comprised range and beam signals, was now being used sufficiently effectively to force the RCM organisation to start planning effective countermeasures. Finally, it was observed that German aircrew, while over the United Kingdom, were making extended use of the Luftwaffe's first class Direction Finding Service in order to position themselves as accurately as possible. In consequence, instructions were issued to the effect that all such W/T transmissions were to be Meaconed.

In order to contend with this enhanced workload, the Operations Room had to be expanded.[20] Maps and associated procedures were retained, but new maps were introduced for each Aspirin fitted with a rotating aerial. These new aerials had the advantage of an attached compass rose, complete with pointer, which conveniently indicated the direction of the jamming transmission. Bromide operations were restricted to a small

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[19] PRO Air 41/46 App."D". p.3.

[20] PRO Air 41/46 App."D", p.4.

display board that indicated available transmitters.[21] Obviously it was necessary to know how many of the active Ruffians were being jammed. Accordingly, a plaque was positioned on the board indicating the German transmitter and the frequency to be jammed. A clerk would then telephone the appropriate field site and issue the jamming instructions. The third responsibility, that of organising the investigation and bombing sorties by No 109 Squadron and the subsequent and important de-briefing of participating aircrews, was retained.[22]

Control of the Meacon transmitters remained much the same as hitherto, but the scale of the Section's activities increased as further Meacon sites became operational. Moreover, because of the earlier success of Meaconing, the German Air Force was forced to turn to their Safety Service network in order to obtain navigational assistance. Fortunately for the RAF only one frequency was involved: to Meacon this, highly specialised equipment was positioned at Henfield in Sussex.[23] To be successful, however, action also had to be swift, and this consideration, together with the specific nature of the work, led to a considerable amount of autonomy being granted to the personnel involved. By now the Special Duties clerks employed in the Operations Room were gaining in experience and increasingly coming to understand the intricacies of their work. As additional facilities became available, and as more commitments devolved on Meacon Control, some of the allocation of jamming capacity was placed in the charge of a

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[21] Ibid.

[22] Ibid., pp.4-5.

[23] Ibid.

Meacon senior aircraftsman, with only the most general supervision in the hands of the Meacon Control Officer.[24]

This officer was still required to be fully conversant with the current situation. He was able to keep abreast of events with the help of the essential information furnished both by RAF Cheadle and the personnel manning the special equipment based at Henfield. Against a background of continuing operations, the Air Ministry and 80 Wing were well aware of the general shortage of transmitters for jamming purposes and the constant need to improve on existing apparatus and techniques. The answers to these and other problems lay mostly with the various Research Establishments, such as TRE, RAE and the GPO's research department at Dollis Hill, which were invariably searching for improved and more powerful transmitters. To increase power and to make Meaconing even more efficacious, German beacons were Meaconed twice [25]. This introduced considerable complications in Meaconing due to interaction, and to enable suitable sites to be chosen, a chart devised by the GPO was used.[26] Starfish Control was the smallest Section, normally being manned by only one officer. In the evening prior to a major German operation, however, it was found necessary to attach one of the clerks from another section, in order to help. Apart from drawing up operational plans, the Starfish Controller was given complete autonomy with the lighting arrangements at, or adjacent to, Starfish sites, and other methods of dummy lighting were to be switched on at his discretion, bearing in mind his intimate knowledge of the current

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[24] Ibid., pp.5 and 8.

[25] Ibid.

[26] Ibid.

air situation. The section maintained a card index giving details and information about each site and this was linked to, and cross-indexed with, a map of the United Kingdom. Large-scale maps of each area were also available if required. For the operation to be successful it was obviously essential for the Starfish Controller to be aware of the current air situation and the direction likely to be adopted by German aircraft when approaching the suspected target. This was achieved by liaison with the Operations Officer and the Headache Controller. If required, further information about beam settings could be obtained from the Scientific Analyst. As reports of German aircraft activity started to come in, tension heightened in the Operations Room and contact was made and maintained with those Starfish Sites, or their local control, likely to be affected.[27] The carrying out of this task in December 1940 was affected by the absence of dedicated telephone lines, rendering it necessary for arrangements to be made with the GPO trunk supervisor in order to obtain the necessary priority. These inefficient arrangements with the GPO were put right early in 1941, just as Domino arrived from TRE. Later on, it was to give way to Benjamin but, meanwhile, in order to make provision for this additional commitment, a further sub-section of Headache Control was created, based on the existing Bromide display and organisation. Significantly, in the beginning, Domino jamming was initiated by the Headache Controller or Duty Wing Commander by personally instructing personnel at Domino sites to jam a particular German ground station frequency.[28] Subsequently, Domino jamming was handled independently by staff at the site concerned, although the closest liaison was maintained with the

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[27] Ibid., pp.25-26.

[28] Ibid., p.6.

Operations Room, thus enabling Benito transmissions and action taken in response to be correlated with aircraft tracks.

Fortunately, the Operations Officer was able to help Headache Control with this and other matters, including arranging for elements of No 109 Squadron to conduct flying operations against the Germans, together with the subsequent briefing of the crew concerned.[29] It was not long before it was obvious that considerable advantage would accrue if these two officers worked together as a team. In order to try to reduce the amount of telephone traffic to and from Stanmore when maintaining contact with 80 Wing's liaison team, a plotting table was installed in the Operations Room complete with special duties' clerks.[30] The latter's task was continuously to plot the tracks of German aircraft from data supplied by the liaison team. By reference to the table, personnel of the Operations Room could obtain the latest information about German air activity, further details of any particular plot being made available on request. At about this time the opportunity was also taken to make some minor adjustments to the presentation of Meacon information. These included displaying a green tally, whenever a transmitter was placed on stand-by due to a reduction in power of the German beacon.

In August 1940, the Luftwaffe began to realise that the RAF had started to take action against their navigation beacons and that, consequently this was why some of their aircrews were experiencing navigational difficulties while over the United Kingdom. One of the first measures taken by the Luftwaffe was to

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[29] Ibid.

[30] Ibid., pp.6-7.

reduce the power of their beacons to the extent that the received signal could no longer be used to stimulate the Meacon transmitter. But this action nullified the use of the beacon for German crews flying over the United Kingdom, so that it could then only be used for 'homing' purposes. Another ploy adopted was to change frequencies and call signs at odd times, but again this only added to the difficulties of their own aircrews; moreover, many signals were intercepted between German aircraft and their respective bases reporting that their direction finding equipment was unserviceable. Similarly, the RAF Y-Service noticed a marked increase in the number of German aircrews requesting Direction Finding assistance, from radio stations belonging to the Luftwaffe Safety Service, while over the centre of England. This was a departure from normal procedure as such transmissions could disclose the position of the aircraft involved.[31] With more equipment being designed and manufactured and an increasing number of jamming stations becoming operational, it had now become essential for the RAF to decide on the organisation best suited to control this fast growing countermeasure organisation.

By 1 September 1940 Germany possessed two beacons and four broadcast stations in Norway, fifteen beacons, one Elektra in Denmark and North France, twenty-one beacons, four broadcast stations in France and one high-powered beacon on the French coast at Cherbourg.[32] In December a second Elektra was introduced and based near Bayeux in Normandy, the two systems together providing a complete lattice over the United Kingdom. The

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[31] PRO Air 41/46, App.“C”, p.9.

[32] Ibid., App.“F” pp.2-3; F.H. Hinsley, *British Intelligence in the Second World War*, vol.1, p.323.

Luftwaffe continued to broadcast Elektra signals which all had to be Meaconed with an increasing, but still insufficient number of channels although, by October 1940, No 80 Wing had acquired ten sites with thirty operational transmitters. Meaconing action was quickly taken and subsequently it was confirmed that the Elektra system was rendered unusable over the whole of the United Kingdom.[33] This jamming capability continued to expand. Even so, resources had to be carefully allocated if the optimum jamming potential was to be attained. This involved selecting the German beacons most likely to be active during any particular raid and it became critical for the Y-Service, in this particular case RAF Cheadle, and also Bletchley, the Government Code and Cipher School, to pass information to No 80 Wing about German beams in use, or likely to become active in the near future. RAF Countermeasures continued to operate along these lines until December 1940 when, on security grounds, and in order to avoid changes at night during operations, a new set of frequencies in the 176-600 Kcs band was introduced by Luftwaffe signals personnel, along with some short-word call-signs. This was a setback for No 80 Wing. Until the new system was understood, forecasting of beacon details by the Y-Service was no longer possible.[34] Successful Meaconing became very difficult and delays occurred until the Y-Service could gather the necessary information from each German beacon as it was operated. Fortunately for the jamming organisation, by the middle of the month the new system was found to comprise four rotas of call signs and frequencies, which were changed daily.

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[33] PRO Air 41/46, p.23 and App.“L”.

[34] Ibid., App.“C”, pp.3-4.

Given this information, pre-operational planning and the subsequent allocation of Meacons then became possible again. Between December, 1940 and 31 March 1941, however, the Luftwaffe increased the number of high-power coastal beacons, which operated outside the four-rota system, and Elektra transmissions. Meanwhile broadcast stations in Germany had been formed into synchronised groups, but some, in the occupied countries, still operated as beacons. These could be identified when they started to send recognition letters in Morse code. In order to counter the high power beacons, Elektra and Broadcast stations, it was necessary to allocate more than one Meacon channel against the German beacon to be masked. Multiple Meaconing caused technical difficulties connected with rejection angles (the area covered by an angle of 45 degrees on both sides of a line joining the Meacon receiver to its transmitter). To overcome these problems, the GPO prepared charts for No 80 Wing indicating which Meacon sites could work together.[35] Moreover, further evidence of the continued success of Meaconing became apparent when German aircrew reported their direction-finding equipment was unserviceable, with the result that a number of German aircraft crashed or, after crews had lost their way, landed in the United Kingdom.[36]

Due to the increase in operational and other commitments during 1941, it became apparent that Aldenham Lodge was not large enough to house all the expanding elements of the up-dated Operations Room and the Wing's Administrative and Technical staffs. It was therefore decided to create a new operations block at

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[35] Ibid.

[36] Ibid., pp.9-11.

an adjacent house, 'Newberries'.[37] Naturally, Headquarters Fighter Command was kept fully informed of all these important details. The Controller's Orders Board now showed at a glance, active German beams and the allocation of countermeasures.[38] So far as Knickebein was concerned, the column headings represented the various German positions under which a plaque would be positioned revealing the operating frequency, immediately the transmitter became active. Beneath each frequency, further plaques would be displayed, indicating the RAF sites and transmitters required for the necessary countermeasures. The obverse of the frequency plaque, with black lettering on a white background, revealed that a site had been ordered to prepare transmitters on the frequency specified. Just as soon as the actual jamming was required, the reverse of the plaque was displayed, with white lettering on a black background. The numerical strength of the Orders Section remained the same as hitherto, but each now had a telephone extension to a Private Branch Exchange (PBX). Actions taken by these individuals were displayed on the Orders Board where use was made of plaques similar to those of the Controller, disclosing the type and numbering of individual transmitters. Four Boards in all were used for this purpose, giving the available jamming sites in a particular geographical area in respect of Aspirin, Bromide and Benjamin transmitters.[39] The clerks passed concise jamming instructions to sites in accordance with the Orders Board. Modulation frequency, keying speed and mark-space ratio were details, however, which normally were conveyed well in advance and were thus not included in the

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[37] PRO Air 41/46 p.40

[38] Ibid., App.“D”, p.10.

[39] Ibid., pp.11-12.

executive messages which were kept as brief as possible. It should be noted that Benito information and Domino transmission details were not included in the above arrangements. Benito matters were handled by the Controller who personally communicated with the sites concerned.

No 80 Wing's actions had been sufficiently successful by January 1941, that little use was now being made of the German Knickebein beam. Consequently, the Luftwaffe decided to change the radio frequencies which, fortunately for the RAF, the new jamming equipment, now becoming available from TRE, was able to accommodate. In addition, the Luftwaffe also reduced the length of time the German beams were transmitted. The effect of these changes required a quicker reaction by the British and thus higher operating standards from the 80 Wing signals personnel involved. In January, too, a second Ruffian beam was confirmed by No 80 Wing as being operational in the Morlaix, Cherbourg area of France and shortly it was noticed that the beams were no longer aligned over a target before the commencement of a raid, as had been the practice hitherto. Moreover, the Luftwaffe started to employ multiple beams in order to avoid jamming action. To make matters even more difficult for No 80 Wing, not all of them were utilized. At one stage, up to nine separate beams were active simultaneously, thus making target prediction almost impossible. No 80 Wing responded by employing Bromide jammers against the Cherbourg beams with a measure of success, although RAF St Athan was bombed in April 1941. By the end of May, however, employment of the Ruffian beams ceased. The third German beam, Y-Verfahren, was then found in three separate locations in France. The Domino jammer was brought into action, but it was to be some time before all the complex details of Benito were unravelled. Domino was then discarded in favour of Benjamin, which jammed the associated Luftwaffe R/T channels although, strangely, there was little Benito activity at the time. While these events were taking place, No 80 Wing was re-organised to accommodate the latest changes introduced by the Germans, including use of the Luftwaffe's first class D/F Safety Service, for normal operational purposes.

Before No 80 Wing possessed its own permanent network of listening stations, the RAF Y-Service passed information about German beam activity to the Liaison Team who then subsequently notified HQ No 80 Wing. In addition the duty Liaison Officer was required to notify Air Ministry and 80 Wing daily of all German beam activity and details of any countermeasures and investigative flights undertaken, together with lists of German Medium Frequency beacons Meaconed and those which, occasionally, were deliberately left for use by Bomber Command. This task, however, was assumed by HQ No 80 Wing itself just as soon as it was able to do so. In due course, therefore, it was HQ 80 Wing which passed this sort of information to their own Liaison staff at Stanmore before 0500 hours each morning, including details of any decoy (Starfish) activity operations, thus enabling the HQFC duty Air Commodore to include details of the previous night's successes and failures of the RCM organisation in his report to the AOC-in-C and Air Ministry.[40] From 28 September 1940 onwards, at the end of the penultimate phase of the Battle of Britain, and as the night blitz gathered pace, this officer was also kept informed of current German beam information. Moreover, the Liaison Team was responsible for sending a Headache report at 0700 and 1900 daily to HQ 80 Wing, covering all appropriate German activity, together with any other items likely to be of operational interest.[41]

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[40] PRO Air 41/46 App.“F”, pp.1-2.

[41] Ibid.

Thus it became necessary to alter the existing displays and procedures and the layout of the new Operations Room was planned with these modifications in mind. They were introduced when the new Operations Room at 'Newberries' was first used on 19 October, 1941.[42] Under these arrangements the Operations Officer was given general responsibility and from their new positions, he and the Controller could see just how many Luftwaffe beacons and beams were active, as well as the extent of any countermeasures being taken.[43] Transmitter and Beacon information were displayed on a separate large board. The setting of each Beam and the estimated target were also plotted as accurately as possible and passed to HQFC at Stanmore. The Controller and Starfish Officer were, of course, fully informed of this important information. The Operations Officer assessed the importance of the Benito range and beam signals, after their origin had been determined by 80 Wing Sites employing D/F techniques and another key RAF Y-Service which, based at a site at Kingsdown in Kent, specialised in the interception of German VHF transmissions. Unfortunately, it was not possible to estimate a likely target from the Benito information so obtained and consequently the data passed to the Controller only disclosed the beam and range frequencies, together with their respective sources of origin. With RAF Kingsdown's assistance, however, information was also acquired about the operating frequency of Benito airborne equipment, together with the estimated position of the aircraft involved.

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[42] Ibid., App.“D”, p.8.

[43] Ibid.

By November 1940 it had generally, but not always become the practice for aircraft of Geschwader KG 26 and Kampfgruppe KGr 100 to act as pathfinders by preceding the main Luftwaffe force. Approaches to the United Kingdom were made from the direction of Brest and the Channel Islands, crews adopting a meandering course until within 20 or 30 miles of their target, when a direct approach would be made. Consequently, the Liaison Team at Headquarters Fighter Command were asked to keep a special look-out for aircraft from KG 26 and KGr 100 and on a number of occasions, Liaison Officers were able to do this and warn HQ 80 Wing accordingly. Negative information, such as lack of enemy action, also was helpful to the Operations Staff at Fighter Command, when considering which and how many Fighter Squadrons to be brought to readiness. Indeed, all of this advance warning became so advantageous to the air defence organisation and others that the list of recipients having access to it became too large. The Air Ministry found that information of such a highly secret nature was by some means, reaching certain authorities in the actual target areas before the attack took place and consequently this wide distribution had to be curtailed. It was therefore decided on 26 February 1941 that the Liaison Officer should only give his beam information to the duty Air Commodore by day, and by night to the Duty Night Operations Staff Officer. The Duty Air Commodore’s Instruction No.18 of 3 June 1941 again stressed the secrecy of the beam information and continued similarly to restrict the distribution.[44] Nevertheless, accurate prediction of the target, sometimes made far in advance of the attack itself, was obviously welcomed by the fighter defence staff

[44] Ibid., App.“F”, p.3.

and in August 1941 the distribution was enlarged to include the C-in-C, S.A.S.O., Duty Naval Staff Officer, Anti-Aircraft Liaison Officer and the Group Commander concerned or his representative.

By way of riposte, the Luftwaffe delayed switching on radio aids to navigation and bombing until the very last moment and sometimes not until after the actual attack had started.[45] HQ 80 Wing was also interested in the tracks of German aircraft employed on carrying out reconnaissance during daylight hours. Such action was often a prelude to a night assault and was frequently associated with the Luftwaffe's essential testing of its radio and bombing aids. By close liaison with the Home Security section at Stanmore, HQ 80 Wing could be kept informed, by their own team, of the progress of a German raid from reports from the ground by the Observer Corps and ARP organisation of occurrences such as flares, fires, high explosive detonations and the like. In this way, it was possible to confirm the approach route adopted by German aircraft to a target and the path chosen for their return to the coast.[46]

2. The Radio Countermeasures Board

The origins of the Radio Countermeasures Board can be traced to 1940, when a series of informal meetings began between representatives of HQ No 80 Wing and members of the effective GEC Research Laboratory, Wembley. It was here in northwest London that many of the essential search receivers and jamming transmitters were designed and subsequently used by the Royal Air Force to such good effect. It soon became necessary, however, to

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[45] Ibid.

[46] Ibid., pp.4-5.

widen the matters being discussed, and under the chairmanship of the Air Ministry Director of Signals, Air Commodore (later AVM) Lywood, the Board became the recognised forum for all matters relating to RCM. From January 1941, the Admiralty and War Office sent representatives to the meetings, as did TRE, a little later on. The work was important; various technical investigations were fully discussed and assessed, before inter-service policy was decided upon. Subsequently, demands were raised on the supply ministries for the necessary items. Later still, in October 1942, it was decided that TRE could act as co-ordinator for GEC and thus the GEC representative withdrew from the meetings. Until March 1942, the meetings were conducted at a fairly informal level, reliance being placed on the authority of the Chairman for decisions to be implemented. But this regime changed on 24 March, 1942, the month when the first meeting occurred of a reconstituted Board, complete with official terms of reference.[47]

The new board was larger and included members of the Y-Service, the three services, the Ministry of Supply, the Ministry of Aircraft Production and the Research Establishments, TRE, ASE, RRDE, and the NPL. In addition, Lord Cherwell, or a member of his staff, attended, as did a United States representative. In spite of these changes, however, the Royal Air Force continued to be the largest user of RCM equipment as it remained throughout the war. Nevertheless, TRE continued to set the technical policy.[48] At first, all went well as the various requirements were clear and unambiguous but, as the RCM war developed, the technical requirements became more complicated and not at all clear. The

[47] PRO Air 29/6148, 29/6149.

[48] PRO Air 20/8953, pp.3-4.

policy that was once comparatively easy to formulate began to depend more and more on the most careful assessments of the relative merits of any new RCM venture, initiated either by Germany or its allies. But such an assessment could not, of course, be undertaken without a thorough knowledge of the current trends in technique and a close study of German reactions.[49] To assist those concerned, TRE, from 1942 onwards, started to issue a series of papers on the design of equipment and, perhaps more important, on the methods of operation and any related effects on tactics and policy. After exhaustive discussion and debate at TRE, these papers were sent to the RCM Board. [50]

3. TRE and Radio Countermeasures

It was no coincidence that the Luftwaffe was experiencing problems with radio beacons and the navigation and bombing beam, Knickebein. Meaconing action against the beacons had begun in a small way in July 1940, and by 20 August 1940, RAF countermeasures had started on a regular basis, including Aspirin jamming against Knickebein, just at the end of the second phase of the Battle of Britain.[51] Cockburn's task was going to take time to complete, and thus some immediate action against the beams was clearly required. As an emergency measure, Addison requisitioned a number of hospital diathermy sets, normally used to produce heat in the human body with the aid of electric current, which, after modification, were used as crude jammers and positioned at Police Stations around the coast. Two of these equipments were modified to cover the 30 Mcs band as jammers, without keying

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[49] Ibid.

[50] Ibid.

[51] PRO Air 26/580, p.3.

facilities, and installed in vehicles containing receivers for intercepting the beam signals. The vehicles were located at Wyton in Huntingdon and Boscombe Down in Wiltshire, where they could be despatched to any specific target area. Telephone tie-lines were then made available and connected to the Filter Room at Fighter Command, where the reports from the listening stations were received by a small team of experts especially formed for the purpose.[52]

Meanwhile, as a precaution, a 50-watt standard RAF Beam Approach Beacon had been modified to enable it to be used, in conjunction with a receiver, as a synchronised transmitter, thereby providing a more subtle form of interference. With this equipment it was hoped to distort the equi-signal path of the beam. If successful, this would divert German aircrews from their desired heading without them knowing it. The equipment was first installed at RAF Wyton but later moved to a more suitable site at Norwich. It was not used operationally, however, for the reason that, up to the end of June 1940, there was no evidence, so far, from the plotted tracks of German aircraft that Knickebein was being used operationally.[53] Nevertheless the jammers were ready for use had they been required. Later, the equipment was adapted so that it could be used as a synchronised transmitter in order to replace the earlier lower-powered equipment. The method employed was to pass a received German signal to a transmitter through a device which enabled the transmitter to be 'keyed' in synchronism with the received signal. Two stations were provided, one about 50 miles north and another 50 miles south of the transmitter site

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[52] Ibid., p.10; PRO Avia 7/601.

[53] PRO Avia 7/601.

at Harlestone, near Norwich. This was called the Deviator method of interference.[54]

Specialist jamming equipment, which had been ordered earlier, started to become available in September, 1940. Some of the new RAF transmitters were high-powered and, given the limited number available, it was decided to site some of these equipments near to the capital and key industrial areas, in order to render German beam signals inoperative during an approach to the target. Others were located near the east and south coasts, to try to provide protection for all the essential ports and, at the same time, cover some of the inland areas with jamming signals.[55] Apart from ensuring that unnecessary jamming was not initiated, thereby avoiding disclosing vital information to the Germans prematurely, it was also important to test the efficacy of RAF defensive measures.

Summary

In this chapter it has been argued that it was necessary for the RAF to have a specialist signals organisation, responsible for countermeasures. It was as well for Britain that the Air Ministry decided to form No 80 Wing when it did in July 1940. Group Captain Addison could not have had an easy task creating an organisation during the first phase of the Battle of Britain. Obtaining and training the required numbers of personnel would have been difficult at any time, but especially so with the United Kingdom expecting invasion at any time. Had the responsibility

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[54] PRO Air 41/46, p.5.

[55] PRO Air 41/46 p.11; Sir Robert Cockburn, KBE, CB, quoted in Colin Latham, Anne Stobbs, *Pioneers of Radar*, p.189.

been left with Fighter Command, it may have proved an unwelcome and untimely diversion at a critical time during the Battle of Britain. Moreover, accommodation had to be found quickly, the minimum requirements being considered to be an operations room and a communications system. These were achieved, and radio countermeasures commenced on a regular basis on 20 August 1940. In order to measure the width of German beams and operating frequencies and to ascertain the effectiveness of RAF jamming, No 80 Wing was allocated control of WIDU, later No 109 Squadron. In order to obtain the information required, this unit often flew in appalling weather conditions, taking off when German raids were either taking place or were imminent. In this way the unit played a key role in the radio countermeasure organisation. Having made life difficult for Luftwaffe crews using Knickebein beams, by means of Aspirin jammers, No 80 Wing then had to take on the Ruffians and start using Bromide jammers towards the end of 1940, without knowing all the X-Verfahren details. Consequently mistakes were made. Meanwhile continuous Meaconing had successfully been taking place against German M/F beacons. None of this would have been possible, however, without the help and assistance of the Y-Service and Air Intelligence, especially the invaluable information forthcoming from No 61 Signals Unit at RAF Cheadle, and to a lesser extent from RAF Kingsdown in Kent. Meanwhile, the Battle of Britain was drawing to a close, although by October 1940 the Luftwaffe was certainly not giving Fighter Command much of a rest. Indeed the need to maintain standing patrols over Kent placed a great strain on pilots and operations staff alike. On the last official day of the battle, 31 October 1940, the Luftwaffe conducted fighter-bomber and fighter sweeps by day but greatly reduced its night activity. By November, it was all over as the Luftwaffe withdrew from the daylight assault of the United

Kingdom. Goering issued new orders for an attack on Britain, but this time it was to be by night. [56]

As more beacons and beams were used by the Luftwaffe, and associated frequencies altered, No 80 Wing adapted to the increase in responsibilities by periodic changes in its organisation. Starfish was placed under its control at the end of 1940. In February 1941, the Y-Verfahren jammer Domino became available and the RAF Y-Station at Kingswood provided vital information about Benito VHF operating frequencies. By the end of May, 1941, Ruffian transmitters had ceased to operate and the stations projecting the third and most advanced series of all the German beams, had been located on the continent and it was at this stage the new Domino jammer was brought into action. While No 80 Wing had been taking action against the German beacons and beams, it had been found essential to maintain the closest of links with HQ Fighter Command. In this way, No 80 Wing could be informed of German aircraft tracks approaching the United Kingdom in order to select, in advance, the most appropriate jamming combination for that particular raid. Moreover, current beam information could be passed from No 80 Wing to its Liaison Team at Stanmore for the benefit of the air and ground night defence organisation. Details of No 109 Squadron's nocturnal activities were also passed to Fighter Command in order to avoid any friendly-fire incidents.

The Radio Countermeasures Board was an important forum, as it provided an interface between the users of countermeasure equipment and industry. It started in a small way, but later expanded and became sufficiently influential to decide inter-service policy. TRE played a large part in its meetings, submitting a

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[56] Derek Wood, *The Narrow Margin*, p.318.

number of papers covering not only the design of new equipment, but also how it should be used.[57]

The Telecommunications Research Establishment based at Swanage, Dorset, had as its antecedents the various Air Ministry Research Stations that produced the Chain Home and airborne radar for the Royal Air Force. In August 1940, in response to the Germans introducing the three blind bombing and navigational beams, Knickebein, X-Verfahren and Y-Verfahren, TRE decided to create a Radio Countermeasure Group which was later to develop into a Division. The RAF was to rely very heavily on TRE for the design and modus operandi for most of its jamming equipment.[58] In this chapter the reasons why it was necessary to form No 80 Wing have been investigated, and an outline provided of the formation's organisation and operations. The following chapter will investigate how German radar was revealed and how Operation Barbarossa in the east came to affect Luftwaffe operations in the west.

[57] PRO Avia 7/2050.

[58] PRO Avia 7/1497; PRO Avia 7/1603.

CHAPTER FOUR: NEW TACTICS AND COUNTERMEASURES

1. German Radar Revealed

In October 1940 a special team comprising Derek Garrard, E.G. Ackermann and Don Stevenson left TRE at Worth Matravers, Swanage, for Dover. Prompted by R.V. Jones, they had been briefed, along with a number of others destined for locations elsewhere, by Dr W.B. Lewis, Deputy to the Superintendent, A.P. Rowe, to search for signals emanating from the German-held coast opposite, especially those which might in any way be connected with fifth-column activities.[1] For this purpose they were equipped with a super regenerative receiver, radar equipment, Yagi aerials and the latest in parabolic antennae. All signals heard were logged and reported to the Admiralty. Most could be identified satisfactorily except for two. These turned out to be Seetakt.[2] The TRE party had found the German naval coastal and gunnery-ranging radar which operated on 375 Mcs.[3] At the time, in London, it was considered that Germany was likely to be developing radar but did not actually possess it. Intelligence indicated that the Germans had installed the Freya Early Warning system, but this had not been confirmed. Here then was the first proof positive of the existence of German radar. In the normal course of events, however, listening posts situated in the United Kingdom were unlikely to reveal short wavelength radar transmissions and thus recourse was made to airborne receivers. Here No 109 Squadron

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[1] R.V.Jones, *Most Secret War*, p.136.

[2] David Pritchard, *The Radar War: Germany's Pioneering Achievements 1904-1945*, p.49.

[3] Interview with Mr Don Stevenson of Bracknell, Berks, former TRE employee, on 11 July 1990.

demonstrated its value and an additional flight was established for this purpose.

In February, 1941, after reasoning that if the Germans possessed coastal radar, then it would be likely that they would also have air defence radar, ADI (Science) Dr R.V. Jones, set about uncovering Freya, the German early warning radar. This he eventually did, with the help of a number of photographic reconnaissance sorties and the invaluable contribution made by his assistant, Derek Garrard, who on his own initiative heard some of the first Freya transmissions on 120 Mcs, and participated in many operational flights as a civilian from TRE.[4] ADI (Science) then became concerned about another air defence radar. This time it was the extremely small but accurate, associated height-finding equipment, Wurzburg. To assist in the process of widening the circle of knowledge of German radar, a Vickers Wellington aircraft was made ready for the purpose, fitted with special equipment, and provided with scientific personnel who volunteered to act as observers. The unescorted aircraft took off from the airfield at Boscombe Down on the evening 7 May 1941, and crossed the French coast at Cap Barfleur. Members of the crew then kept a good watch for German aircraft as the Wellington made its way to Cap de la Hague, St Michel, Cancale, De Talbert, Ile de Ushant, Pt de Penmarch, Ile de Croix, Pt de St Gildas, St Malo, Jersey, and home via Seaton to Boscombe Down. Nine pulse transmissions, in the band 550-580 Mcs with a peak repetitive frequency (PRF) of between 3000 and 4000 cps were recorded and their source of

[4] R.V.Jones, *Most Secret War*, p.191.

origin approximately located. It was in this way that further details of the 53-centimetre Wurzburg became known.[5] (See Figure 12)

2. X-Verfahren (Ruffians) and a Change in Tactics

After a lull of some weeks, German attacks were resumed in February 1941, by He 111s of KGr 100 against targets situated in the United Kingdom, employing X-Gerät. This time, however, the Luftwaffe significantly changed tactics. All the X-Verfahren transmitters available to the Luftwaffe at the three sites were switched on during operations, thus producing nine simultaneous operational frequencies. Rapid changes of frequency were then made by the German technicians to the fine beams during the actual attack, with the result No 80 Wing found that instead of an expected frequency spacing of 0.50 Mcs, divided between the three sites in two well defined bands frequencies appeared approximately 0.25 Mcs apart. These were apparently allocated at random and divided between the three sites. Naturally, this made identification of the frequencies more difficult. Identification letters, however, continued to be imposed, but these were not altered when a frequency change was introduced. These German measures made target prediction almost impossible, especially as the Cherbourg transmitters (quickly repaired after No 109 Squadron's attacks) could be used for either approach or cross beam purposes.

No 80 Wing tried to cope with the situation by jamming the Morlaix and Cherbourg beams with the Bromide jammers, located in the Devonshire, Bristol and Wiltshire areas, while the Calais beams were dealt with by the London group of sites, supplemented

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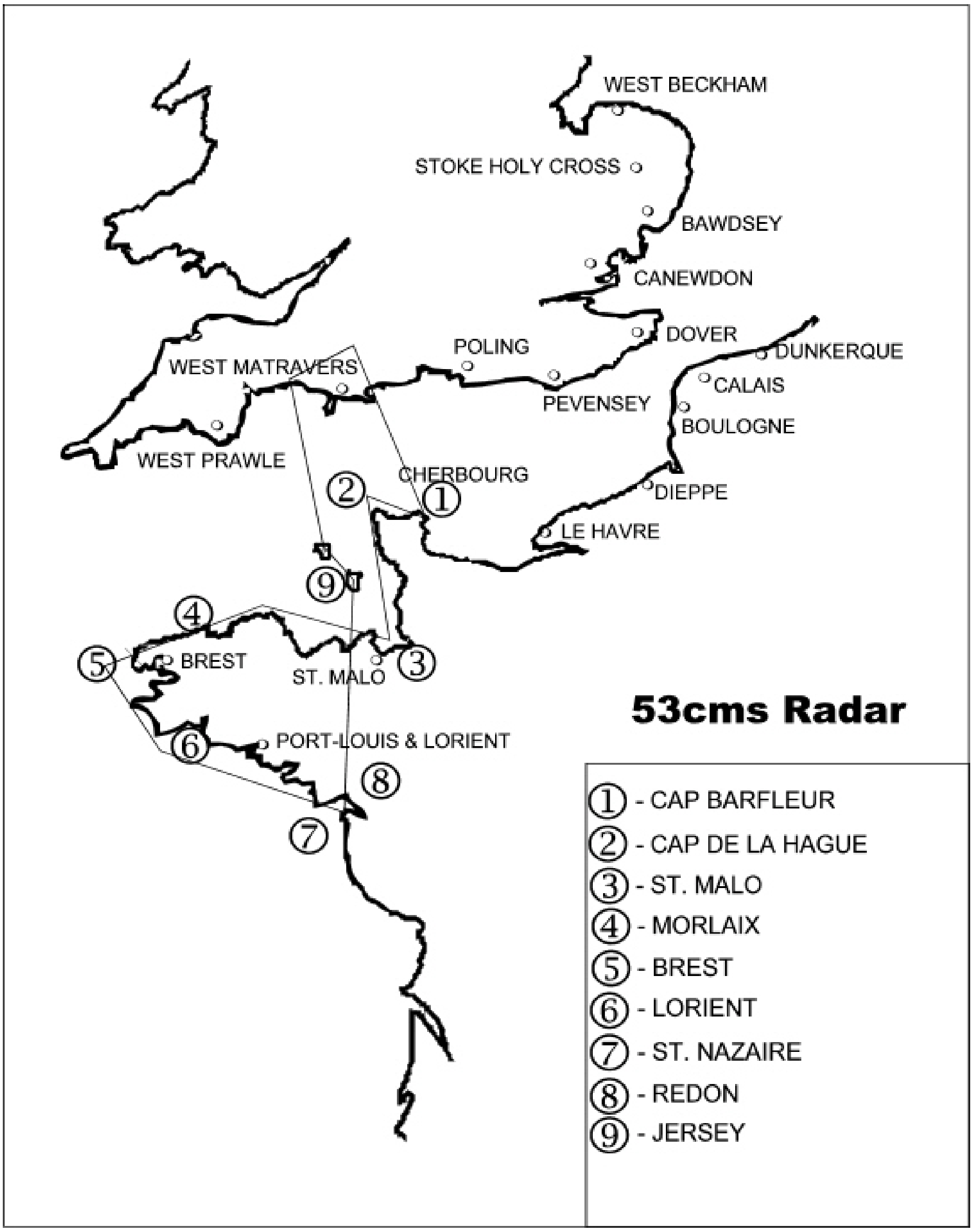
[5] PRO Avia 26/1850, Investigation Flight No 1, Report No 5/16A.



AVIA 26/1858

Figure 12
German 53cms Radar

by the Midland and Northern Bromides.[6] Obviously the closest co-operation was required between listening stations and jamming transmitter sites if countermeasures were to stand any chance of success. It transpired that Luftwaffe changes of frequency were implemented when their lead aircraft approached the target. Such was the state of No 80 Wing's communications that by June 1941 it only took between three to four minutes to follow these particular frequency changes and pass the necessary information from Listening to Jamming site.

Conventional bombing attacks had started against the X-Verfahren transmitters in the Cherbourg peninsula with Armstrong Whitley aircraft in November 1940. Indeed, the Royal Air Force had gone to considerable effort in order to attack small and difficult targets by night. Such a policy indicated just how seriously the Ruffian threat to the United Kingdom was taken at the time. With the recent change in tactics the Ruffians were still a threat to the United Kingdom, and thus, in February 1941, it was decided to launch a new series of conventional bombing attacks against the German beam transmitters, located in the Cherbourg area, but this time with better aircraft. To enable the unit to carry out this commitment, it was given an additional flight of Wellingtons and, later in the year, the Squadron was enlarged again so as to include three flights. These were employed, respectively, on the development of the RAF narrow-beam bombing device, or Oboe, investigations on behalf of the RAF Y-Service and RCM investigative sorties.[7]

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[6] PRO Avia 7/1611.

[7] Michael Cumming, *Beam Bombers*, pp.21-22, 25, 28, 30-31.

Understandably, in the circumstances, the Benito beam signals received by the well-established network of air and ground monitoring stations remained under investigation. The results arising from this inquiry helped to confirm the view of Air Scientific Intelligence that the Germans were developing a device known as Wotan, or Y-Verfahren, which was likely to be used as an advanced bombing system. This system involved making a distance measurement along a beam which measured the difference in phase angle between outgoing and incoming modulations.[8] TRE, in particular, co-operated in the examination of this latest device and, although its principles took some time to unravel, accuracy of the system of the order of some ninety yards in range was determined in January, 1941.[9] Its signal differed from the two earlier systems, changing from dots to dashes and back again without passing through the equi-signal. Moreover, three sources in France were confirmed namely, Cassel, Beaumont on the Hague peninsula and a transmitter in the area of Poix, 20 miles south west of Amiens, which was the home airfield of another specialist flying unit 111/KG 26. Countermeasures, code-name Domino, were set up, the first equipment being based at Alexandra Palace, in north London, where use was made of the existing television sound transmitter. The receiver, with its associated relays, was located at a BBC station nearby, where a high fidelity cable was available for passing the various tones to the transmitter. Receiving equipment was later moved to Parliament Hill, slightly nearer to central London, where it was found that reception was better.

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[8] PRO Air 20/1624; PRO Air 20/1627.

[9] TRE Report RCM No 5/2 quoted in PRO Air 41/46, pp.20-21.

Despite adverse weather conditions over the United Kingdom in January 1941, seven major night assaults by the Luftwaffe took place, mainly against London and the ports, together with a similar number of lesser attacks. Most were supported by X-Gerät and Y-Gerät beams, KGr 100 and 111/KG 26 having been joined by a third Pfadfinder unit, 11/KG 55, which was equipped with Knickebein. By now every major British city in the south was provided with an X-Verfahren jammer. Moreover, German aircrew started to complain about interference to their X-Gerät equipment, although in most cases it was not enough to prevent the bombs being released. As the bad weather continued into February 1941, the number of German attacks against Britain was scaled down. The jammer Domino was ready for operations against Benito by the middle of February 1941, thus making both the Cherbourg and Cassel controls subject to countermeasures simultaneously. Plans were also made to install additional transmitters at the two existing Domino sites and to establish a new site to the west to afford protection for the Southwest and South Wales. Later the same month, a second Domino was sited at Beacon Hill, north of Salisbury.[10] During this period H.Q. No 80 Wing believed that the German Air Force only used Benito occasionally, the aircraft tracks being carefully followed and recorded, the task being made easier because only aircraft of 111/KG 26 were so employed. The position, however, was complicated. Swansea was the target for three consecutive nights beginning 19-20 February. During the first night KGr 100 bombed with the aid of X-Gerät, but did not lead the attack. This unit helped to start proceedings the next night and was joined later by 111/KG 26 employing Y-Gerät, and

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[10] PRO Air 41/46, p.21.

the two units were present again over Swansea on the third occasion, each using their own distinctive bombing systems.[11] The Luftwaffe reported no interference from No 80 Wing jammers, on any of three nights. Although, after analysis of these and subsequent bomb plots, it was confirmed that Benito was an advanced bombing aid capable of great accuracy. The precise details continued to elude Air Staff Intelligence, TRE and the Royal Aircraft Establishment (RAE).[12]

March brought better weather and with it a resumption of heavy raids against the United Kingdom, London and the sea port towns again attracting the majority of the bombing. On most occasions target marking was provided by KGr 100 and 111/KG 26, sometimes over the same target, and for the first time Luftwaffe records make reference to partial interference from No 80 Wing.[13] By the middle of the month there is little doubt Domino was having some success, but there were difficulties, including the German bombing of the transmitters at Beacon Hill, north east of Salisbury, on the night 11-12 March.[14] These were being used to provide Meacon action against the range tone of Benito. Sometimes No 80 Wing was at fault, as on the night 16-17 March, 1941, when a defective crystal which had been installed in error caused the transmitter to re-radiate on two frequencies 400 Kcs apart.[15] Later on in the month, when Benito-aided attacks became heavier, two incidents, when a number of participating aircraft failed to receive

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[11] Ken Wakefield, *Pfadfinder*, p.110.

[12] PRO Air 41/46 pp.21-22.

[13] Ken Wakefield, *Pfadfinder*, pp.128-129.

[14] PRO Air 40/2242, Benito Operations Report No 6, dd.17 Apr 41.

[15] PRO Air 40/2242, Benito Operations Report No 7, dd.18 Mar 41.

the all-important bomb release signal, occurred. This seemed to confirm that Domino was having an effect after all, although German records do not appear to substantiate this claim.[16] Bad weather intervened after the 22nd of the month, preventing further heavy raids from taking place at night, although Bristol and Avonmouth were attacked on 29-30 March by aircraft from KGr 100, seven of them using X-Gerät, while four bombed visually. At the same time five aircraft from 111/KG 26 used Y-Gerät successfully and without interference.[17]

The Germans used the Morlaix transmitters less in June and by the 21st of the month ceased operations entirely. This was possibly due to the transfer of much of the Luftwaffe in the West to the Mediterranean and Eastern areas. The Cherbourg and Calais stations, however, remained as active as ever, three changes of frequency being recorded on several separate occasions. Evidence now became available about the efficacy of the countermeasure code-named Bromide, much of it stemming from statements made by captured German aircrew.[18] Luftwaffe records are silent on the matter of interference at this particular time, although they do indicate that the X-Verfahren system had been in use as an accurate bombing aid since the night 13-14 August 1940.[19] Nonetheless, when RAF St Athan was attacked on the night of 28-29 April 1941, a British analysis of the raid confirmed the efficacy of the Bromides, as the crossbeams had been jammed successfully,

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[16] PRO Air 41/46, p.22; Ken Wakefield, *Pfadfinder,* p.128.

[17] Ken Wakefield, *Pfadfinder*, p.129.

[18] AWA Report BC/G/2 dd. Feb 41; ADI (K) Report No 341/1941, both quoted in PRO Air 41/46, p.17.

[19] Ken Wakefield, *Pfadfinder,* p.42.

but not those used for the approach to the target.[20] The latter originated too far away to be affected. Bombs were dropped correctly on line but were found to be a mile out so far as range was concerned. The Ruffian system continued to be employed up to the end of May 1941, and beyond, but with diminishing effect.[21] In fact the Ruffians were withdrawn from operational use in July, but Luftwaffe signals personnel continued to transmit on 66-77 Mcs. for deception purposes.

3. HQ No 80 Wing and No 109 Squadron

HQ No 80 Wing, also, had to take care to ensure that the countermeasures adopted by the RAF did not interfere with the normal radio communications of other RAF units and, indeed, of the Royal Navy and the land forces. This they did with the aid of No 109 Squadron which was also employed on an investigation to see if the Luftwaffe was making use of Bomber Command's Splasher navigation beacon.[22] Other tasks, which this busy unit was given at this time, included checking to see whether the signals emanating from the BBC transmitter at Droitwich were being used by the Luftwaffe for navigation purposes, and ascertaining the range and extent of allied radio transmissions. Much later on, No 109 had to check on certain unsynchronised transmissions to find out if they could be used as a navigation aid for German aircraft launching the V1 flying bomb.[23] Meanwhile, over the next three months, September-November 1940, the United Kingdom continued to be subject to wide-ranging attacks by

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[20] AWA Report BC/G/5 dd. May 41, quoted in PRO Air 41/46, p.17.

[21] Ibid.

[22] PRO Air 41/46 p.106, App.“B” pp.4-5.

[23] PRO Air 20/1626, p.2; PRO Air 40/2242.

aircraft under the direction of French-based Ruffian and Benito transmitters.[24] The attacks continued in 1941, and were similar to those that had occurred previously. The severe bombing of Coventry on the night 8-9 of April being a good example. Seven crews of KGr 100 used X-Gerät, while five resorted to visual bombing, a pattern followed by aircraft of 111/KG 26 with their Y-Gerät. No reasons for this were given in the operational records but it is likely that RAF countermeasures were responsible. Thirteen aircraft of 11/KG 55 also took part, employing a combination of Knickebein and visual bombing, aided by flares.[25]

Domino action was taken whenever it was practicable to do so and, during this period, it was noted by HQ No 80 Wing that only on two occasions was the release signal received by more than 25 per cent of the attacking force.[26] Subsequently, however, captured aircrews from three aircraft of 111/KG 26 brought down on the night 3-4 May 1941, confirmed that they were losing confidence in Benito due to RAF countermeasures.[27] How true this feeling was generally, however, is difficult to confirm. Fortunately, certain valuable components were recovered from these aircraft, including a complete Y-Gerät apparatus, albeit in a damaged condition. This sort of good fortune and the British skill in exploiting it provided the knowledge to make a big difference in future jamming capability.

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[24] Ken Wakefield, *Pfadfinder*, pp.49-54

[25] Ibid. p.142.

[26] PRO Air 41/46, p.22.

[27] A.I. 1 (K) Report No. 240/41 & A.I. (K) Special Report to ACAS (I) 10 May 41 quoted in PRO Air 41/46, p.22.

4. Benito Dissected

The heavy raids of April continued for the first half of May, Merseyside, Clydeside, Nottingham, London and Birmingham being particularly hard hit. Again the three Pfadfinder units were generally present and marked the targets as hitherto. After the 17th of the month the pace of attack slackened, although there were still a number of small and isolated raids conducted against ports and airfields. In the meantime RAE, Farnborough, had carried out a detailed examination of the Y-Gerät equipment captured on the night 3-4 May, and found that it contained a separate course panel and an independent range/distance panel. The former contained a mechanical analyser for interpreting the characteristics of the Benito beam, which was maintained in synchronism by means of a magnetic clutch, controlled by signals from the ground beam transmitter. Subsequent tests revealed that the synchronising mechanism was particularly susceptible to jamming and, if such action were taken, then erratic indications would be displayed on the course panel. Accordingly, preparations were made to jam the Benito beam signals under the code name Benjamin.[28] In its Report No 5/2 the RCM Section of TRE explained that in order to ascertain range, the phase difference which existed between a tone radiated by a ground station and the same tone on its return, when re-radiated by an aircraft, would need to be measured. The Report also listed the equipment required for such a ranging system: a ground radio station, which operated on a frequency in the 42.2 – 45 Mcs; an airborne receiver, in fact the FuGel.7 tuned to 43.1 Mcs; a five watt airborne transmitter (46 – 47.8 Mcs) which could be modulated by the audio output of the receiver; a ground

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[28] PRO Air 41/46, pp.22-23.

receiver tuned to the frequency of the airborne transmitter and a phase analyser.[29]

The aircraft transmitter was a critical component of the system, enabling bearings to be taken on the aircraft transmissions. The Luftwaffe ground station could then vector their aircraft on to the beam as the target area was approached. This obviated the need for aircraft to fly straight and level along a narrow beam for a period of time, when they could be highly vulnerable to detection and attack by elements of the United Kingdom's integrated air defence system. Instructions to the crew of German aircraft, passed either by W/T messages or Morse code, included the bomb-dropping signal. The ranging tone was sometimes, but not always, discontinued whilst these instructions were passed. The report confirmed that the beam station was located near to the ranging station and used an aerial mounted on a turntable. TRE calculated the output of the transmitter, which gave amplitude modulated at 2000 cps, and was keyed to produce dashes at 180 per minute with a mark-space ratio of 8:1, and was keyed. This keyed output was fed to the aerial array, the elements of which could be phased to produce two sets of alternating and overlapping lobes. Aerial phasing was switched in synchronism with the transmitter keyed to take place in the middle of each dash. The result gave a very narrow beam or equi-signal zone with numerous weaker and subsidiary beams on each side. The beam, it transpired, turned out to be of the Lorenz type, except for the equi-signal which consisted of dashes transmitted at 180 to the minute, with a marked-space ratio of 8:1, instead of the usual continuous note. The first or second half of each dash would become relatively

[29] Ibid.

weaker as an observer, facing the transmitter, moved to the left or right of the equi-signal zone until eventually the mark-space ratio would appear to be 4:5. The high keying speed made aural analysis almost impossible and the apparent change in the mark-space ratio accounted for the many reports of either dots or dashes which were received earlier.[30] The crew of the aircraft therefore had to have a mechanical analyser, which turned out to be the FuGe 28A, known as the Y-Gerät. Details of this are to be found in the Royal Aeronautical Establishment's Report EA/33/8 Department No WT 18.[31]

With this information TRE decided to recommend jamming the Benito beam signal, by causing erratic signals to the course indicator. The jamming was implemented by transmitting a dash signal similar to the German original but at a slightly different keying rate, with the aid of a number of available low-powered transmitters. By the end of May six of these were available, the first coming into operation on the 27th of the month. More followed, and by October some 30 Benjamin jammers were covering Benito sites at Cassel, Mount de Boursin, Poix, St Valerie, Cherbourg and Commana.[32] However, although subsequently the beams were active, it was difficult to associate the few German aircraft tracks plotted over the United Kingdom with beam flying. Existing Domino stations were maintained at a high state of readiness but were not used owing to the lack of German air activity within range. Eventually, the British authorities decided to rely on Benjamin only

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[30] PRO Air 41/46, App.“K”.

[31] Quoted in PRO Air 41/46, App. “K”, p.3; PRO Air 20/1624.

[32] PRO Air 41/46, p.34.

and the jamming of the associated German R/T channels.[33] In the meantime, Manchester was bombed at the beginning of June and this was followed on the 13th by an attack on Chatham, when two aircraft of KGr 100 were lost to RAF night fighters.

5. The Germans Move Eastwards: Operation Barbarossa

During June 1941 the Morlaix transmitters were used less frequently and ceased radiating altogether on 21 June 1941. Frequency changes, however, continued to be made on the Cherbourg and Calais transmitters, three changes on one day being recorded on several occasions, in an attempt to disguise the reduction of Luftwaffe strength in the West.[34] In spite of these spoof radio transmissions, RAF Air Intelligence had known about the movement of Luftwaffe units to the East for some time. Indeed, Enigma had disclosed in May that an attack on the Soviet Unit was planned. All three Pfadfinder units were affected and the first to move was 11/KG 55 which left Chartres on 18 June, 1941 bound for Lubinie. Four days later, Germany attacked Russia hoping to vanquish it in a matter of weeks.[35] Hitler was therefore wrong in his assumption that the whole Soviet system of government would collapse quickly, once the Russian people were given an opportunity to rise against their leaders.[36] On the 16th of the month KGr 100 moved from Vannes to Chartres pending re-organisation and possible expansion. Thus the Luftwaffe was

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[33] Ibid.

[34] PRO Air 41/46 p.17; Ian Kershaw, *The 'Hitler Myth': Image and Reality in the Third Reich*, p.180.

[35] Alan Clark, *Barbarossa: The Russian-German Conflict*, p.44.

[36] Rolf-Dieter Müller 'From Economic Alliance to a War of Colonial Exploitation' in Research Institute for Military History, Potsdam, Germany (eds.) *Germany and the Second World War:* Vol. IV, *The Attack on the Soviet Union* p.135.

charged with conducting a holding war against the United Kingdom, with a reduced number of air units. The plan was to attack ports and shipping coincident with an intensification of the U-boat campaign. The small remaining bomber force was assisted by elements of KGr 100 and 111/KG 26, but this state of affairs was not to last for long. The former unit moved to the east on 19 July and the latter, the last of the three to leave France, was operating over Russia by the end of July.

6. Luftflotte 3 and Expansion of RAF Jamming Capability

In spite of this reduction, which in August 1941, left Luftflotte 3 in the West with 84 serviceable bombers out of a total of 203 aircraft, the RAF could not afford to relax its guard, especially as the latest types of German bomber were now to be made available for anti-shipping operations and attacks upon the United Kingdom's ports and docks.[37] The first of these was the new Do 217E1, which was to be followed by later variants. The greatly improved Dornier was soon joined by a new variant of the Junkers, the Ju 88A4, and these two new types of aircraft were to bear the brunt of most of the Luftwaffe's bombing campaign in the West until the end of the war. The Luftwaffe, however, also possessed a marked ability to be able to move flying and support staff quickly over long distances, a notable feature of the Luftwaffe's organisation insisted upon by Erhard Milch.[38] Moreover, HQ No 80 Wing believed that, even with the bulk of the German air force elsewhere, it would hardly be likely that the German

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[37] Ken Wakefield, *Pfadfinder*, p.182.

[38] PRO Air 41/10; David Irving, *The Rise and Fall of the Luftwaffe*, p.92.

countermeasure experts would become quiescent and leave the initiative to the United Kingdom.[39]

Information gleaned from intelligence sources now indicated that certain changes and improvements to the Knickebein system were about to take place. Accordingly, No 80 Wing decided to embark on a plan to modify its transmitters and increase the number of sites and transmitters. As it did so, the Luftwaffe increased the number of its Knickebein transmitters to twelve.[40] These were carefully sited on the coasts of Northern France and Holland (with one in Norway), thereby adding to the number of accurate beam intersections which could be obtained by their bomber crews while attacking targets in, or adjacent to, the United Kingdom. Moreover, in September 1941, transmissions were heard on frequencies other than 30, 31.5 and 33.5 Megacycles.[41] Specialist jamming equipment, which had been ordered earlier, now became available to the British with the added advantage of considerable extra power.[42] For good reason, given the limited number available, it was decided to site some of these near to both the capital and key industrial areas, in order to render Luftwaffe beam signals unusable during an approach to the target. Others were located near the East and South coasts, to try to provide protection for all the essential ports and, at the same time, cover some of the inland area with jamming signals. This development made it possible to withdraw the modified hospital Diathermy equipment employed as a temporary jamming measure at selected

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[39] Unpublished history of No 80 Wing, PRO Air 41/46, p.30.

[40] PRO Air 41/46 p.31, and App."A", pp.2-3.

[41] Ibid., p.31.

[42] Ibid., p.11.

police stations. Far from being returned to their original owners, these sets could not be spared by No 80 Wing; they were rebuilt as quickly as possible and promptly re-deployed at some of the newer specialist jamming sites.[43]

7. Mediterranean Excursion

During the autumn of 1941, the Air Ministry received a request from the Army to jam German VHF tank communications in the 28-34 Mcs band. Barrage jamming with an airborne jammer, Jostle II, was considered to be the only practicable method and consequently No 109 Squadron was given the task by HQ No 80 Wing. The unit was required to find the right aerials for six Wellington aircraft, suitably modified for service in the Middle East, which were to be used in conjunction with standard aircraft radio equipment converted by the Marconi-Ekco Company, with assistance from TRE.[44] In a remarkably short space of time the aircraft and crews flew to Egypt, the first three leaving England on 14-15 October 1941. One complete crew had been found from within No 109 Squadron, the others from Bomber Command, and all the aircraft were extensively employed during the opening phases of the Libyan campaign. Most of the aircraft involved were damaged, and one was lost carrying the Army proponent of radio countermeasures, Colonel R.P.G. Denman. The results were inconclusive; some reports, arising from the interrogation of prisoners of war, claimed that tank communications were interrupted during the battle. Later on, the British Army decided that they no longer wanted to jam German tank communications; obviously the 8th Army decided that they would gain more

[43] Ibid., pp.4-5.

[44] PRO Avia 7/2072.

intelligence by listening in to the conversations between German tank crews.[45]

During the latter part of 1941 and early 1942, the German M/F beacon schedules became progressively more complex in an attempt to avoid the worst of No 80 Wing's Meacon activities. System changes occurred at frequent intervals, sometimes as short as twenty-five minutes, and beacon power progressively reduced. But the Luftwaffe also faced the problem of preventing crews of an expanding Bomber Command using the Luftwaffe's beacon organisation and the easily identifiable high-powered, unsynchronised broadcast transmitters, for navigation purposes. Thus, in September 1941 the broadcast stations started to transmit in synchronised groups, except when the Luftwaffe required them for navigation purposes. Moreover, the times of transmission were also reduced to cover the periods of German air operations and the frequency bands in use greatly restricted. All the time these changes were taking place, No 109 Squadron continued to monitor the efficacy of the British jamming programme in general, and 80 Wing's Meaconing in particular. Several Meacon test flights in September indicated that German beacons were effectively covered over the United Kingdom, at least. But therein lies a dilemma. How far would a Luftwaffe pilot rely on beacon information, if he suspected it was false or being Meaconed? After all, dead reckoning methods of navigation were always available to him, and, indeed, these were often used before and after flying the beam.[46]

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[45] PRO Air 40/2242; Michael Cumming, *Beam Bombers*, pp.41-45.

[46] Ken Wakefield, *Pfadfinder*, p.75.

Nevertheless, Meaconing proved to be very effective, and on 12 October 1941 forced one of the new Do 217E bombers to land at Lydd, in Kent, the crew lost due to faulty radio bearings arising from Meaconing action and the aircraft being almost out of fuel. This created great excitement at HQ No 80 Wing, not only because of the capture of the aircraft itself, which was more or less intact, but for its equipment and especially the new Knickebein and Blind Approach receiver, E.Bl.3, which after examination proved to possess some 34 different frequencies.[47] This incident was followed by a similar one in November, when a Heinkel He 111 belly-landed near Helston in Cornwall. Later the same month, on the 26th, a Junkers 88 landed wheels-down at Chivenor, near Barnstaple. All three events were attributable to navigation errors caused by faulty radio bearings arising from RAF Meaconing. At the time No 80 Wing's Meacon system was expanding, being completed in May 1942, when the last station was installed at Marske. The whole project comprised 60 channels to be operated from 16 sites. These were obviously well chosen, as there were no additions for the remainder of the war in Europe, although somewhat understandably, aerials and equipments had to be continuously updated and improved. The programme of work included providing 159-foot high masts and expanding the number of available channels.[48]

Summary

As this chapter has argued it seems incredible that after a year of war, and despite possession of a copy of the Oslo Report

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[47] PRO Air 41/46, pp.36-37.

[48] Ibid.

and knowledge of the Graf Spee's aerial system, some authorities in London believed that Germany was only developing radar and did not actually possess it. Not everyone was of the same opinion, however, and certainly not ADI (Science), Dr R.V. Jones. The TRE team corrected the error when they detected the German coastal radar at Dover in October, 1940, thereby confirming that the Germans did, after all, possess radar. Soon R.V. Jones, helped with Intelligence reports, started to deduce that if Germany had developed coastal and gun-ranging radar, then there would be no reason to suppose that they did not possess other types, including radio-ranging and air defence sets. He promptly set out to confirm his deductions and acquire as much information as possible about early warning and height-finding systems.

After a lull of some weeks, air attacks were resumed against the United Kingdom in February 1941, but this time new tactics were adopted by the Luftwaffe in order to avoid the worst effects of No 80 Wing's jamming. For the first time, during bombing operations, all three X-Verfahren were switched on, producing nine different frequencies thereby making target prediction very difficult, if not impossible. In view of this situation, the Bromides were re-distributed to cover the capital, ports and docks; additionally the standards of co-operation between Listening Stations and Jamming sites were raised. These recent changes in Ruffian operating techniques confirmed that X-Verfahren remained a threat to the United Kingdom, and consequently further bombing of the German transmitters at Cherbourg was ordered. This time, in order to accomplish the task, No 109 Squadron was enlarged and allocated a better aircraft, the Vickers Wellington.

Meanwhile, the Benito signals remained very much under investigation and, in January 1941, it was concluded that the Luftwaffe was developing Wotan, or Y-Verfahren, an advanced bombing and navigation system of great accuracy. Three Benito sites were identified in France, together with a user flying unit, 111/KG 26, which was based at Poix. Domino equipment, the first jammer to be used against Benito, was then set-up and located at Alexandria Palace. The weather in January 1941, however, was not conducive to bomber operations. Nevertheless, London and the ports were attacked by the Luftwaffe during the month, mostly supported by X and Y-Verfahren together with the third component of the Pfadfinder force, 11/KG 55. By now, every major city in the South of England possessed a Bromide and the first Domino was ready to begin operations in the following month, February 1942; a second Domino was also positioned at Beacon Hill, Salisbury. With the aid of these new arrangements it was soon established that all the elements of the German Pfadfinder force were frequently over the same British target employing different systems, although, strangely, not always leading the attack. X-Verfahren, however, was destined not to last as a Luftwaffe bombing aid employed against UK targets. The Morlaix transmitter was used less and less in May and June, 1941, as more of the Luftwaffe was moved Eastwards. However, the Cherbourg and Calais transmitters remained active, with many changes of frequency occurring during bombing operations. Throughout this period some success with Bromides was confirmed, but in the following July the last of the Ruffians were withdrawn. For deception purpose, the Luftwaffe cleverly continued to transmit on the X-Verfahren frequencies and in doing so deceived No 80 Wing for some time. In April, heavy raids continued against the United Kingdom, X and Y-Verfahren beams continued to be used and 11/KG 55 was present on most occasions, bombing with the aid of Dead Reckoning navigation and Knickebein. It was during this period that HQ No 80 Wing began to accumulate evidence of the effectiveness of Domino during these attacks, although German records seldom refer to such jamming.

Captured Luftwaffe aircrew however, when interrogated, frequently stated they were losing confidence in the entire system. The capture of a complete Y-Gerät, albeit in a damaged condition, improved the situation and enabled a new jammer to be devised. The month of May saw a continuation of the heavy raids of April. The capital, ports, Nottingham and Birmingham were all heavily bombed with the assistance of the three Pfadfinder units, which were invariably present. The raids, however, tended to slacken off after 17 May. RAE Farnborough was then able to conduct a detailed examination of the Y-Gerät equipment, acquired on the night 3-4 May. Having acquired a better understanding of how the system worked, the British authorities decided to jam the Benito beam signals, under the code-name Benjamin. By the end of May, six of these devices were available, and they were to be followed by a further 24 in October. Domino was not entirely forgotten, however, and the existing stations were maintained at a high state of readiness, in case they were required. This chapter sets out all the early and subsequent ground-based measures taken against X and Y-Verfahren. So far, the Royal Air Force had fought and won a defensive radio war. One incident was now about to occur which was to change the situation.

Volume Two of Two

The Offensive Phase

CHAPTER FIVE: 1942 – THE YEAR OF THE WATERSHED

1. The Channel Dash

In February, 1942, after experiencing a long and hard Russian winter for the first time, the German army, under the direct command of the German Head of State, was unexpectedly forced by the strength of Soviet resistance into a second year of campaigning. Remarkably, Hitler, in spite of all his many and heavy responsibilities as Chancellor, and also those of the day-to-day control of his armies in Russia, remained obsessed with Norway, believing that the Allies intended to invade Northern Norway at an early date. He considered it to be the zone of destiny in this war and to back up his beliefs he had already sent the *Tirpitz*, his largest battleship, to Trondheim in the previous month, and others were to follow.[1] Here his fleet became a potential threat to allied convoys carrying much needed supplies to the Northern Russian ports.[2] He now turned his attentions to his own naval force blockaded in the heavily defended French port of Brest, comprising the Battle Cruisers *Scharnhorst* and *Gneisenau* and the Cruiser *Prinz Eugen*. The Battle Cruisers had been there for nearly a year, during which time they had received the attentions of the Royal Air Force, but without significant effect. Some hits had indeed been achieved by Bomber Command, but the damage had easily been repaired.[3]

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[1] Werner Rahn, 'The War at Sea in the Atlantic and in the Arctic Ocean' in the Research Institute for Military History, Potsdam, Germany (eds.) *Germany and the Second World War: Vol. VI, The Global War*, p.444.

[2] Ibid. pp. 442-443

[3] Adolf Galland, *The First and Last*, p.141.

TRE and No 109 Squadron had taken advantage of the situation to embark upon experiments with an early form of ground-controlled bombing, which was eventually to develop into a device called Oboe, but could not achieve any better results.[4] Hitler appreciated that the ships presented a threat to allied shipping in the Atlantic and that their presence in Brest attracted a considerable tonnage of bombs, which might otherwise have been dropped on Germany. Nevertheless, he concluded that the RAF sorties against the ships would continue only for as long as they remained seriously undamaged. He therefore decided to withdraw the force to Germany, where it could be used in the defence of Norway and act as a potential threat to allied convoys to Russia. He achieved this by executing an audacious and well-planned dash through the English Channel, Operation Thunderbolt, under the command of Vice Admiral Ciliax. The authorities in the United Kingdom had, of course, realised that such a course of action might be taken by the Germans and had issued a joint service plan to deal with just such a breakout as early as 29 April, 1941, under the code name Fuller.[5] Ten months later, the Admiralty acting on intelligence received, requested the Air Ministry to activate Operation Fuller on 3 February 1942. This action involved alerting elements of the three operational home-based commands, Coastal, Fighter and Bomber.

Thus, when the German force sailed from Brest, on the night 11 February, under unfavourable meteorological conditions, a

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[4] Michael Cumming, *Beam Bombers,* p.51.

[5] Command Paper 6775, dated March 1946 (HMSO*), Report of the Board of Enquiry appointed to enquire into the circumstances in which the German battle cruisers Scharnhorst and Gneisenau and cruiser Prinz Eugen proceeded from Brest to Germany on February 12th 1942, and on the operations undertaken to prevent this movement*. p.3.

depression followed by a warm front, the British forces concerned with this operation had been fully alerted.[6] Unfortunately for the British, the execution of Operation Fuller did not proceed smoothly. HMS *Sealion,* a submarine stationed off Brest on the night in question, failed to see or hear the German ships leaving port. Next, individual Lockheed Hudson aircraft of Coastal Command conducting Stopper and other patrols off Brest and in the Channel area, experienced ASV failure, thus leaving a gap of some three hours in the radar surveillance cover between 1940 hours and 2238 hours, during which time the German force left port. The German ships were ordered to sea at 2200 hours, after a two-hour delay, occasioned by a Royal Air Force raid.[7] The force then proceeded to steam up-channel under strong sea escort, unobserved, in a North Easterly direction until 0825 hours on 12 February, by which time they had been joined by a strong air escort of up to two-hundred and fifty fighter aircraft.[8] The first radar plots of the German ships and aircraft then appeared on the Operations Table at Fighter Command; but they were not recognised as such at the time.[9]

Part of the problem had begun earlier when for some days prior to the breakout the German signals staff had, for the first time, decided to jam the Channel CHL radars of Fighter Command, at a level low enough to avoid suspicion. During the actual passage, in order to disguise the jamming for as long as possible,

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[6] Ibid.

[7] Adolf Galland, *The First and the Last*, pp.140-167.

[8] Werner Rahn ‘ The War at Sea in the Atlantic and in the Arctic Ocean’ in Research Institute for Military History, Potsdam, Germany (eds.) *Germany and the Second World War: Vol. VI, The Global War,* p.423.

[9] Sholto Douglas, *Years of Command* (Collins, 1966), pp.163-164.

full power was used at first intermittently, but later continuously. This left little doubt that this was not a British reliability problem, but that the air defence radars were being deliberately jammed. This interference was incomplete, however, and at least two stations, at Hartland Point and Beer Head, managed to track the German ships, with their strong fighter escorts, and hence the appearance of at least some plots in the operations room at Fighter Command. By 1042 hours the two larger ships were identified for the first time but by now the force had sailed well up channel. Thus it was not until this late stage in the transit that Operation Fuller was implemented. It was too late and all the many and often brave actions subsequently undertaken by the Royal Navy and Royal Air Force, against the three ships failed to halt their progress towards Germany, with one exception. As was established in 1946, magnetic mines laid in the mouth of the river Elbe by Bomber Command at 2300 hours on 12 February damaged the *Scharnhorst* and the *Gneisenau.*[10] The Terms of Reference of the Board of Enquiry into this incident precluded allocating blame, but obviously the AOC-in-C Coastal Command must accept some responsibility for the failure of the Hudson ASV patrols, which permitted the German ships to escape out of Brest and into the Channel unnoticed. Similarly, AOC-in-C Fighter Command has to accept that there was inordinate delay before the German force was reported by his air patrols and identified as such by the reports from his radar stations, thus precluding early implementation of Operation Fuller.

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[10] Command Paper 6775, dated March 1946, (HMSO) *Report of the Board of Enquiry appointed to enquire into the circumstances in which the German battle cruisers Scharnhorst and Gneisenau and cruiser Prinz Eugen proceeded from Brest to Germany on February 12th 1942, and on the operations undertaken to prevent this movement.* p.15.

Hitler was thus successful in his aim of returning his ships to Germany, helped by superb planning and the decision to sail in appalling, but suitable for him, weather conditions. He thereby gained a tactical victory but, in doing so, RAF air defence radar had been deliberately and widely jammed for the first time, a practice which, hitherto, both sides had refrained from adopting for fear of retaliation. The British were extremely sensitive about the Chain Home radar and had deliberately not jammed the German radar. Now, however, the door had been opened and offensive jamming techniques could be freely adopted by the Royal Air Force.[11] There had, however, been one occasion in the past when the Royal Navy did jam German coastal artillery. It occurred in February 1941 when an allied convoy in the Channel came under very heavy gunfire. With the aid of experimental jammers and monitor receivers, belonging to the Royal Navy, installed in the Dover and Folkestone areas, jamming took place, whereupon the German gunfire ceased immediately.[12]

2. Freya, Moonshine: Mandrel and Wurzburg

Of course, before embarking upon an offensive campaign it was essential to know details of the German equipment. Much was already known about German radar, especially the early warning device called Freya, thanks to ADI (Science) who was able to make use of information coming from the various intelligence sources, such as Enigma, the Y-Service, interrogation of prisoners of war and the research establishments like TRE and RAE. Indeed, during 1941, the RAF had come to realise that the German Freya early

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[11] PRO Air 20/8953, pp.30-34.

[12] Derek Howse, *Radar at Sea: The Royal Navy in World War Two*, p.82.

warning network was as well developed as the British Chain Home and thus allied aircraft were under observation by the Luftwaffe well inland in South East England, as soon as they had gained a reasonable height.[13] (See Figure 13) Consequently, the RAF asked TRE to address the problem. In October 1941 TRE proposed the use of six aircraft carrying a low-powered Mandrel barrage jammer. This arrangement could reduce the detection range of Germany's early warning system, to a distance of less than 20 miles along some 200 miles of occupied coastline. (See Figure 14) The proposal was not accepted at the time for the reasons given earlier in the Chapter. After the Channel Dash, however, a contract was placed with GEC Research Laboratories, Wembley, for the design and production of such a jammer.[14] But in spite of the Intelligence available and the information gleaned from the sorties conducted by No 109 Squadron, there were still significant gaps in the British knowledge of German radar. One area concerned Wurzburg, the accurate German air defence radar, which operated on 53 centimetres. It was suspected of being capable of finding the height and also the plan position of an aircraft. In order to confirm these suspicions and to obtain further information, Dr R.V. Jones, with the active support of Dr R.B. Lewis of TRE, suggested to the authorities that a Commando type raid should be carried out on the German radar station at Bruneval, on the French coast. Such an attack was indeed mounted successfully by Combined Operations on 27 February 1942 and, as a result, much additional information was gleaned about this particular radar system.[15]

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[13] PRO Air 20/1492, App.“A”.

[14] PRO Air 20/8953, p.28.

[15] PRO Avia 26/1872; George Millar, *The Bruneval Raid*, pp.21-22, 187-190.

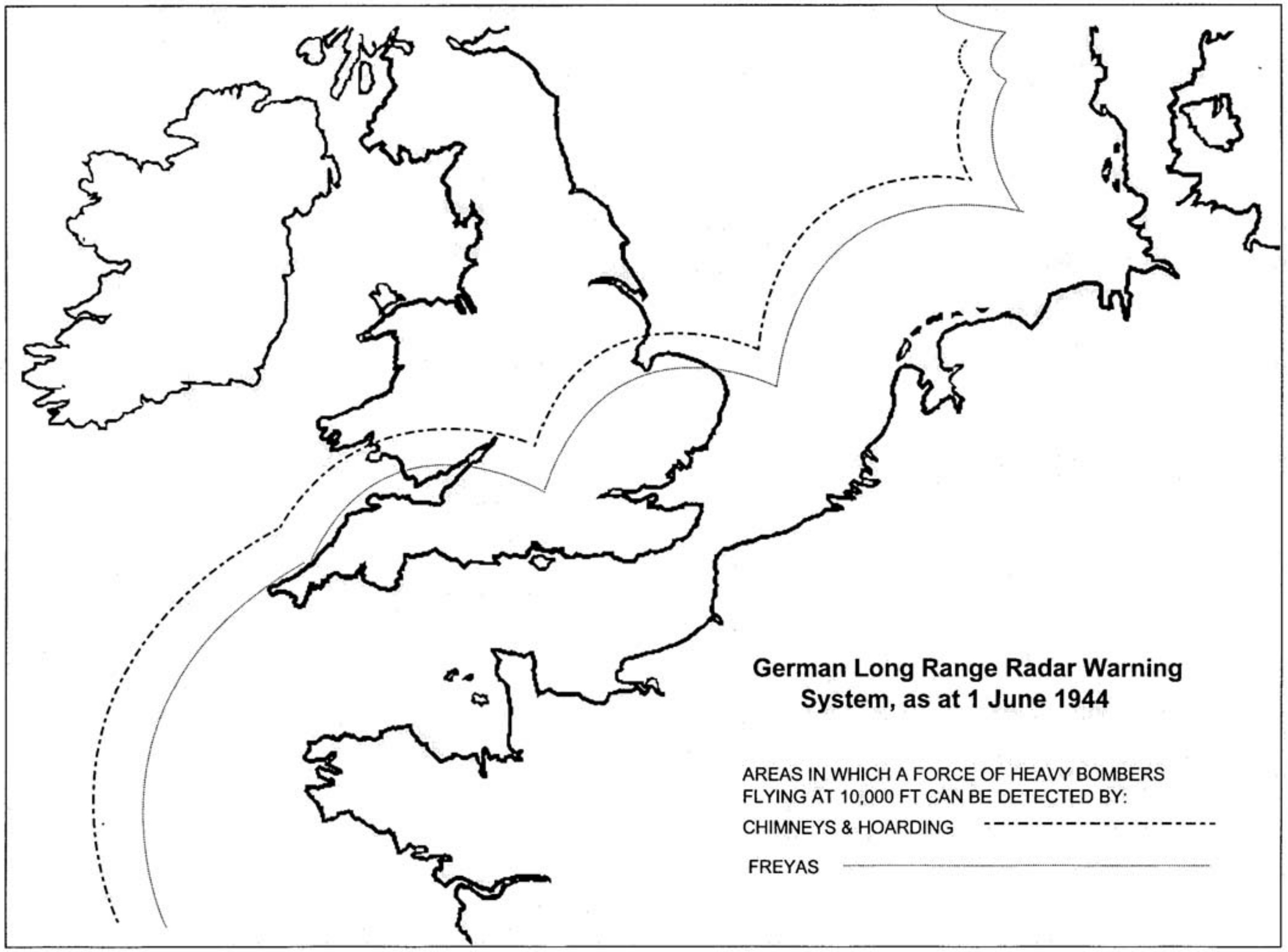

Figure 13

German
Long Rang
Radar

AIR 20/1492

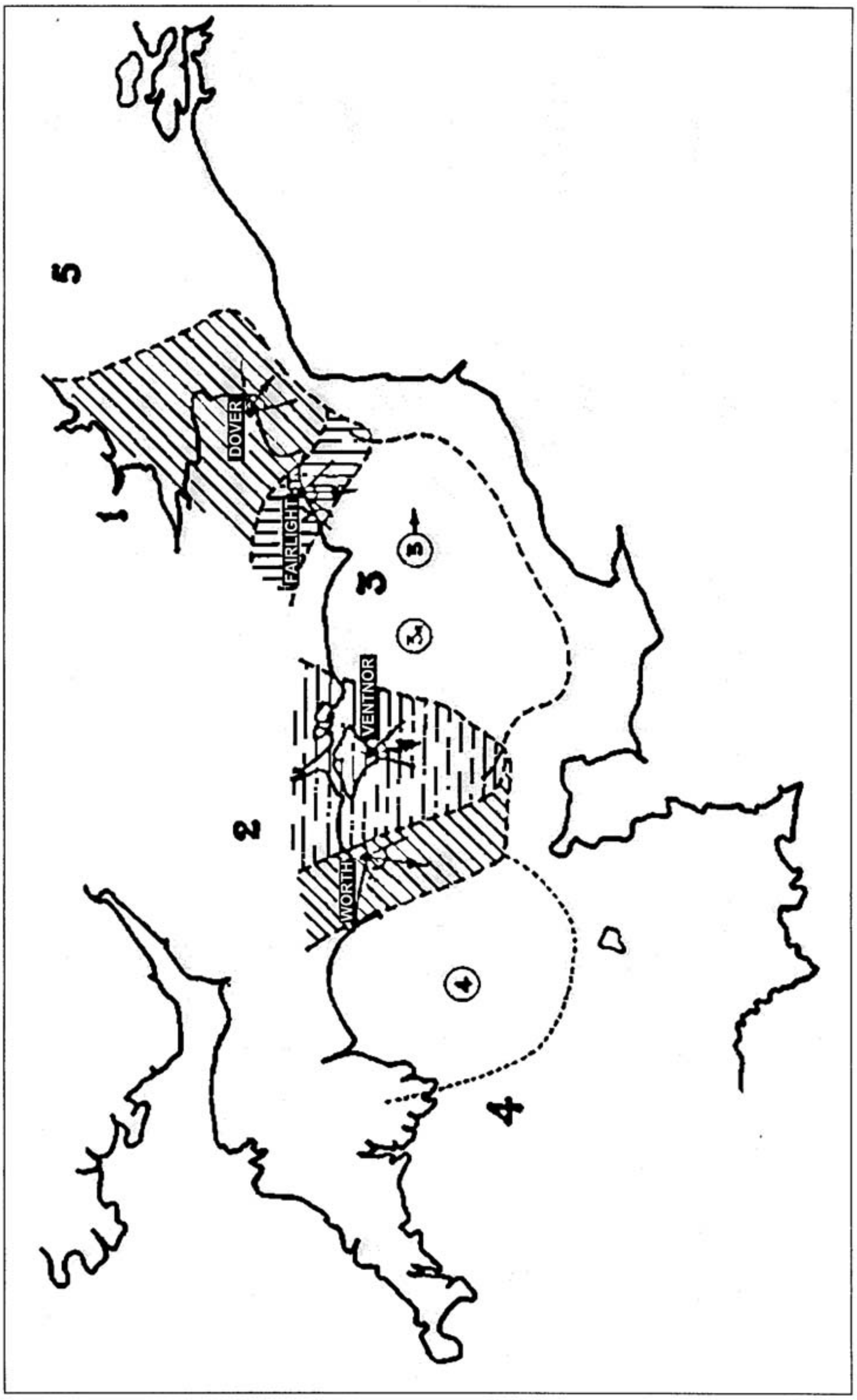

Figure 14
Mandrel

AIR 20/1454

By this time, however, HQ 11 Group was becoming concerned with the German radar which was successfully detecting their fighter aircraft conducting sweeps over occupied France, known as Rhubarbs, and bomber aircraft escorted by fighters participating together in Circus Operations over the Pas de Calais area of France. In an attempt to overcome this problem, and also possibly to provoke the German fighter aircraft to come up and fight, Dr R.V. Jones told a meeting at HQ No 11 Group, at RAF Uxbridge on Monday 2 March, that it would be quite feasible for a single aircraft to simulate a whole formation on the German Freya early warning screen, with the aid of a device called Moonshine.[16] This involved a receiver in an RAF aircraft detecting pulses from German radar stations and sending the pulses back in a longer form, in order to make it look like a whole formation. Realising that such a measure could be used to advantage during both types of operation, Circus and Rhubarb, and also possibly as a means of reducing casualties, a subsequent meeting in the following May recommended that an additional squadron of Defiant fighter aircraft should be made available to No 11 Group and employed as follows: six plus aircraft to be fitted with Moonshine and six plus aircraft to be fitted with an airborne jammer, Mandrel, for use against Freya.[17]

Eventually, after some delay, an additional Defiant Squadron, No 515, was made available for this purpose by the Air Ministry and based at RAF Northolt. But there was still reluctance on the part of the RAF to commence airborne jamming and no less a person than Sir Henry Tizard, Scientific Adviser to the Air Council, wrote to Sholto Douglas personally drawing his attention to the

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[16] PRO Air 16/590; PRO Air 20/ 1461; PRO Air 20/1462.

[17]PRO Avia 7/2712; PRO Air 20/1454.

possible disadvantages of employing such measures.[18] The AOC-in-C Fighter Command, believing that the advantages outweighed the disadvantages, subsequently decided to start Moonshine operations as soon as possible but for the time being left Mandrel jamming for later.[19] By extreme effort, TRE produced the first 20 Moonshine sets in ten weeks, in time for the initial operations in July, 1942, when nine Defiant aircraft were in the air at the same time, successfully engaging Freya with Moonshine.[20] Later, Moonshine was used operationally on fifteen occasions between 17 August and 8 November 1942. As time went on, however, the servicing position of No 515 Squadron became difficult, due to lack of spares, and there were few, if any, Defiant aircraft available as replacements. Moreover, it was not easy to fit Moonshine equipment into a Mandrel fitted aircraft or replace Mandrel with Moonshine. But more and more Mandrel requirements started to take priority over Moonshine at the request of Bomber Command, which was beginning to realise the advantages of using such equipment. As a result, HQ Fighter Command decided to ask Air Ministry for a replacement for the ageing Defiants.[21]

The Air Ministry agreed and the Squadron received Beaufighters in lieu. These, however, turned out to be the Mark 2 variant and not the requested Mark 1 or V1, which were unavailable. Nevertheless, Moonshine was in use for the rest of 1942 and for some time it gave the impression on German Early

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[18] PRO Air 16/590.

[19] Ibid.

[20] PRO Air 20/1461, PRO Air 20/1462.

[21] PRO Air 20/1455, p.130; Martin Streetly, *Confound and Destroy*, p.17.

Warning screens of large formations of bomber aircraft, especially formations of the Flying Fortress belonging to the US Army Air Force, as they approached the French coast.[22] Luftwaffe fighters were diverted from the actual raid, which was taking place simultaneously, to meet the perceived threat, thus reducing losses.[23] At the end of the year, however, the spread of Freya frequencies outside the range of Moonshine and the introduction of the more powerful and longer range Giant Wurzburg into the German coastal chain rendered the use of Moonshine, with its limited range of frequencies, uneconomic. For these reasons and because Mandrel jamming was taking priority, Moonshine was phased out. The sagacious Dr Cockburn, however, removed all the equipment from No 515 Squadron for use on a future and greater occasion.[24]

3. The Baedeker Raids and Daylight Attacks

Heavy bombing did not take place, as expected, against the United Kingdom in the autumn of 1941. Instead, air attacks continued on a smaller scale until April 1942 when the cathedral cities started to be bombed in strength. These signalled the start of the so-called Baedeker raids and were a direct consequence of the heavy and successful assaults by Bomber Command on the German towns of Lübeck and Rostock.[25] It was also during this month that Ruffians were again used operationally after a period of nine months. The Luftwaffe mounted attacks in daylight too, when there was suitable cloud cover. These raids were often effective

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[22] PRO Air 20/1455.

[23] PRO Air 20/8953 pp.29-30.

[24] Ibid.

[25] Ian Kershaw, *The 'Hitler Myth': Image and Reality in the Third Reich*, pp.182-183.

and always a nuisance; in order to avoid situations where No 80 Wing's jammers had to be switched on in daylight, unnecessarily, arrangements were made for appropriate meteorological forecasts to be provided, thus enabling the transmitters to be switched on only when necessary and in the areas likely to be affected. The city of Norwich featured prominently in the Baedeker campaign.[26] On the 27 April 1942, a mixed force of Heinkels, Ju 88's and Dorniers attacked the railway station which soon went up in flames. The associated rolling stock then became engulfed by an inferno, which spread to other parts of Norwich. Water, gas and power utilities were severed, hampering the work of the Fire and Civil Defence services. During the ninety-minute attack twenty factories were destroyed and one thousand and two hundred and fifty people made homeless. The Luftwaffe returned to Norwich on 29 April 1942 when aircraft from 11 KG 2, KG 30, KG 40 and KG 55 attacked the city and the surrounding area, although this time the city was better defended with 252 heavy and other anti-aircraft guns.[27] On the night 8-9 May 1942 the Luftwaffe seemed to have been intent on destroying what was left of the place and returned to drop some sixty-three metric tons in and around the target area, notwithstanding an improvement in defences.[28]

4. Norwich 8-9 May 1942

The first notification of a likely raid that evening opened with a report from Cheadle at 2208 hours to HQ No 80 Wing indicating the Luftwaffe M/F beacons had changed to System ten, earlier in the day. Consequently, all appropriate RAF Meacons were

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[26] Derek E. Johnson, *East Anglia at War*, pp.90-92.

[27] Ibid.

[28] Ibid.

re-allocated to that system number accordingly. Two minutes later, reports started to come in that the Cherbourg Benito beam was active on 42.8 Mcs and Ruffians were also active on 68.0, 70.5 and 76.1 Mcs. This information was promptly passed to the Scientific Adviser for analysis and to the Controller, who placed appropriate RCM on standby. At 2215 hours the Wireless Reconnaissance Flight of No 109 Squadron, now based at RAF Upper Heyford, was contacted and two sorties arranged, numbered 1386 and 1387, to investigate Ruffian beam activity and to report on the effectiveness of No 80 Wing's jamming. The Flight was advised of the Ruffian frequencies; the routes to be followed, timings and other aircraft details. Clearance for these flights was then requested through the Liaison Section at HQ Fighter Command. At 2216 hours while this was being done, Radlett Radio Receiving Room reported hearing a Lorenz-type signal on 33.025 Mcs, but this had not been heard by any other Watcher Site.[29] Four minutes later, Bolt Head Watcher Site reported the telephone line to their D/F site at Bolt Tail was unserviceable, adding that the GPO had already been advised. Further Cherbourg Ruffian activity was then notified, this time on 78.0 Mcs. This information was passed to the Scientific Adviser for analysis and to the Controller, who was still considering how much RCM to place on standby. RAF Upper Heyford was informed of this new development but, so far, there was no sign of any German air activity. At 2251 hours Sidmouth reported hearing Morse code dots in the Knickebein band on 31.8 Mcs, although no D/F bearing was available. Consequently, all Watcher Sites were asked to check but only Sidmouth had only heard the signal and thus no further action was taken.

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[29] Ibid. App.“E”, p.1.

By 2252 hours, the situation was thus:

Cherbourg –	41.8 Mcs Benito beam active
	70.5 Mcs Ruffian beam active
	70.0 Mcs Ruffian beam active
	71.1 Mcs Ruffian beam active
Boulogne –	68.75 Mcs Carrier Wave only

RAF jamming had not yet started and there was still no sign of German air activity. This all changed, however, at 2323 hours when two raids were reported thirty miles south of Dunkirk, the German aircraft heading in a northerly direction. The Controller ordered Benjamin jammers to transmit on 42.8 Mcs, even though there was still no sign of the Benito range signal and Bromide jammers to transmit on 70 Mcs and 70.5 Mcs.[30] Two minutes later the situation changed to:

Cherbourg –	73.5 Mcs Ruffian beam active;
Boulogne –	74.0 Mcs Ruffian beam active;
Boulogne –	68.75 Mcs Ruffian carrier wave only.

The Scientific Adviser was notified of these changes, as was the Controller, who arranged jamming cover for the Ruffians transmitting on all three active frequencies, pending confirmation of the precise frequencies from the Scientific Adviser. No 109 Squadron was kept fully informed of these latest events. By 2330 hours, four German aircraft were plotted on the table at HQ No 80 Wing, and one minute later Sidmouth reported that the Knickebein signals received on 31.8 had ceased. These were then discounted as only Sidmouth had heard them. Two minutes later, notification

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[30] Ibid. App.“E” p.2.

was received from Home Security, via the Liaison Section HQ Fighter Command, of the presence of fire some 25 miles South West of Norwich. This, however, was the remains of a fire started during a previous raid that had re-ignited.[31]

On being informed of this event, the Starfish Controller contacted the local control for further details. At the same time the Controller decided to jam the Cherbourg Ruffian beam which was now active on 73.5 Mcs, Radlett Receiving Room being advised of this action. At 2334 hours it was reported that the Benito ground range station at Cassel was transmitting on 42.5 Mcs. The Controller's reaction was to order the Domino jammer at Parliament Hill to be brought to Standby, for action on this frequency. So far, however, no Benito controlled aircraft had appeared on the table. Eleven minutes later, the four German aircraft already plotted, were now off the Dutch coast and heading North and the Starfish Controller was preparing a Starfish site on the East coast for possible action. So far no Knickebein beam activity had been notified. At 2347 hours, the Controller brought a second Domino to Standby and consequently Beacon Hill at Salisbury was alerted, in case it should be needed on 42.5 Mcs. At 2358 hours the Controller's Information Boards indicated that the Cherbourg Ruffian beams were being jammed on 73.5 Mcs and 68.75 Mcs; the Benito ranging signal was being jammed on 42.8 Mcs; and a Domino had been placed on Standby to cover Cassel Benito. It was at this point that the Scientific Adviser informed the Controller that the German Ruffian beam deployment was now complete, with the beams being laid in the Norfolk area. This news was promptly passed to the duty Air Commodore at HQ Fighter

[31] Ibid. App."E" p.3.

Command, for action and for information to the duty Group Captain in the Air Ministry. RAF Kingsdown then confirmed that, so far, no German aircraft had been heard actually using Benito. [32]

At 2359 hours, the Starfish Controller decided to contact those Starfish sites in the Norfolk area that could possibly be brought into use. Three minutes later the Cassel Benito beam was reported transmitting on 43.0 Mcs. The Controller then ordered the Domino jammers to transmit on this frequency, the Receiving Room at Radlett being advised of this action. At 0005 hours the following day, the Controller, acting on the latest advice available, ordered the Bromides to jam the Ruffians on 74.0 Mcs. Five minutes later, RAF Cheadle reported that the German M/F beacon system had changed to System 12 and consequently the Controller decided to re-organise Meacon cover accordingly. By 0018 hours the four Luftwaffe aircraft flying north and subsequently northwest, off the Dutch coast had reached the latitude of Norwich and turned west towards the city. Two minutes later the Boulogne Ruffian beam became active on 67.25 Mcs, and the Controller ordered Bromides to jam on 67.25 Mcs and 74.5 Mcs, the Receiving room at Radlett being informed of these actions as usual. The final analysis by the Scientific Adviser at this time confirmed that there had been no directional change to the Ruffian beams and that they remained in the Norwich area. By 0030 hours three Luftwaffe aircraft were heading towards Norwich; five minutes later Parliament Hill reported hearing German aircraft, call sign BD, calling their ground station T2. At 0040 hours, when all appropriate jammers were in action, the first of the German aircraft crossed the Norfolk coast, their presence being confirmed at 0043 hours when flares were

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[32] Ibid.

dropped about three miles Southeast of the City, just South of Starfish site 43 (B). Seven minutes later, Parliament Hill reported hearing German aircraft re-radiating on 42.5 Mcs, the Benito range signal. Consequently the two Domino jammers, previously brought to standby, were ordered to transmit on this frequency.[33]

At 0052 hours Norwich reported to Starfish Controller that high explosives had been dropped and flares and fires could be seen to the South of the city. He promptly ordered local control to ignite the short Starfish decoy at site 43 (B), at Bramerton, as eight further Luftwaffe aircraft were now approaching from the East. At 0105 hours, RAF Cheadle reported yet another change to the German M/F beacons, this time to System thirteen. Meacon Control quickly re-allocated cover accordingly. A minute later, confirmation was received that Starfish 43 (B) had been ignited successfully at 0102 hours. By 0110 hours the plotting table indicated that sixteen German aircraft were approaching Norwich from the east and northeast; eight minutes later ten German aircraft were reported over the city, with nine to follow. Significantly, at 0120 hours, No 109 Squadron confirmed that No 80 Wing's current jamming was effective. At 0125 hours, the Starfish Controller lost contact with Norwich Starfish Control but, fifteen minutes later, as the Controller ordered the Splasher at Sale to be cut, and Bomber Command was informed of this action, contact was re-established on the tie-line. Apparently Norwich Telephone Exchange had been evacuated and, in doing so, the process of switching over to the Emergency Board had been omitted. About thirty bombs were reported being dropped in the vicinity of Norwich, with eight high explosive bombs and one

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[33] Ibid. App."E" p.4.

unexploded bomb being collected within eight hundred yards of short Starfish 43 (B). No fires were reported within the city itself although one was reported at Stoke Holy Cross. German aircraft were now plotted as wandering between the city and the coastline.

By 0148 hours, however, only seven German aircraft remained in the vicinity of the city, the remainder having returned to base. Seven minutes later, as the last three aircraft were crossing the coast, it was estimated that some thirty aircraft were involved in the raid on Norwich. By 0200 hours the plotting table was clear, but the night's work was not yet over; the M/F beacons were changed again twenty minutes later, this time to system seven, and the Meacon cover had to be re-organised accordingly. The Bromides were then switched off, as the Ruffians became inactive.[34] Fighter Command did not have a very successful night. Some fifty-five German aircraft were reported over the United Kingdom that night, thirty-five of them in the Norfolk and Suffolk area. There were thirty-seven RAF night fighters available for interception purposes on this occasion, but the Luftwaffe reported no aircraft lost after this raid. Squadron Leader Trousdale of No 409 Squadron intercepted a Heinkel 111 in the area, with the aid of the GCI at Orbey; as his attack was unsuccessful, no claim was subsequently made. No German aircraft attacking Norwich were shot down on this occasion.[35] Nevertheless, thanks to the timely and effective countermeasures conducted by No 80 (Signals) Wing, the city Norwich was saved.

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[34] PRO Air 41/46, App."E" p.5.

[35] PRO Air 24/558, HQFC Night Intruder Summary, 1 May-31 May 1942.

5. Russian Adventure

Allied convoys taking vital war material to Russia had become subject to severe attacks by German aircraft, surface ships and submarines. Crews of Luftwaffe aircraft based at Banak and Bardufoss became adept at shadowing convoys in order to report details such as course and speed to headquarters. Early in 1942 the Luftwaffe strength in the area consisted of some sixty bombers and thirty dive-bombers, but by June the numbers had risen to one hundred Ju 88 bombers, thirty dive-bombers, fifty torpedo bombers and thirty long-range reconnaissance aircraft; the situation was becoming worse for the British, and as the numbers of allied ships damaged and sunk rose, drastic action was obviously required. Early the same month a meeting was called in the Air Ministry, which decided to apply the same Meacon tactics, which had proved to be so successful in the United Kingdom, from bases to be established in North Russia. This was known as the CB Scheme. Installation of appropriate equipment became the responsibility of No 80 Wing and Royal Navy personnel were to operate the Meacons.[36] The Meacon apparatus was soon assembled, tested and packed at Dollis Hill, and despatched under a commissioned officer from No 80 Wing. The next convoy sailing to Russia turned out to be PQ 17 and consequently the Meacons were loaded aboard this convoy's destroyer escort. Two British submarines were also to provide protection for PQ 17, along with two anti-aircraft ships and eleven smaller craft. In immediate support were two British and two American cruisers. The convoy was subjected to heavy attacks on 4 July when four merchant

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[36] PRO Air 20/6148; PRO Air 20/6149; Minutes 4th RCM Board Mtg. 2 June 1942, quoted in PRO Air 41/46, p.38.

ships were sunk, German aircrews being assisted in finding the convoy by the transmission of signals emanating from shadowing aircraft. It was known that the battleship *Tirpitz* had left Trondheim on the day before, but there was no further news of the movement of this ship or of the other heavy German ships in the area.

That evening the First Sea Lord, Sir Dudley Pound, fearing that the convoy would face an overwhelming attack by strong German surface forces, prematurely dispersed it. This fatal decision led to great loss of lives and the sinking by German aircraft and submarine of a further twenty-one allied Merchant ships, out of a total of thirty-nine.[37] Fortunately for the success of the CB Scheme, the escorts carrying the Meacon equipment then returned safely to port in the United Kingdom, where the packing cases were unloaded prior to a second attempt. This occurred on the 19th of the following month, when the party comprising a detachment Commander and one NCO of No 80 Wing, together with twelve RN operators, specially trained in Meacon procedures, left a British port bound for Russia. This time the destroyers selected for the task, *Marne, Martin, Middleton* and *Blankney*, sailed direct, without convoy responsibilities, and arrived at Grasnaya five days later. Unfortunately the equipment was found to be badly damaged when unloaded and, because of the poor repair facilities available, considerable effort was required before it could be made serviceable. Sites for the transmitters and receivers had already been selected with assistance from the Russian authorities but these soon proved to be unsuitable, mainly because the Soviets had not appreciated the importance of the VHF link

[37] Bob Ruegg and Arnold Hague, *Convoys to Russia*, pp.39-43.

between the two sites.[38] Fortunately other sites were found, at Vaenge and Polyarnoe and, while not ideal as they were on opposite sides of the Kola inlet, communication between the two was eventually established two months later. It took another three months, however, before the necessary technical and barrack accommodation could be completed and occupied. Moreover, the actual installation of the Meacon equipment was not an easy task. Apart from the severe weather conditions and the intermittent power supplies, other difficulties arose. Ground contours prevented the correct horizontal spacing of vertical aerials. The station was eventually and successfully operated with aerials spaced at 102.5 feet. Power and coaxial cables, however, could only be buried at intervals and most pickets had to be set in concrete. More importantly the VHF link could not be used between the two sites because of the close proximity of the front line and the Germans. Instead, a telephone connection had to be improvised making use of the submarine cable passing down the inlet. Above all, however, British relations with the Russian allies remained difficult and uncooperative. The two vehicles that housed the M24 transmitter and the three-phase diesel generator arrived at Archangel at the end of September. Very adverse consequences resulted from the Soviet port authorities allowing this equipment, along with two petrol-electric sets, switches and spares to be sent by rail to the interior of Russia. None of it was retrieved until mid-November, when it was found that the generator was badly damaged and the diesel cylinder block cracked. In order to obtain replacements the

[38] PRO Air 41/46 p.38.

RAF officer in charge re-embarked for the United Kingdom, returning with the necessary spares as quickly as possible.[39]

A listening watch was finally established at the receiving site and on 23 February 1943 German signals were heard in sufficient strength to drive the Meacon jammer. With this news it was hoped to support the next convoy sailing to the United Kingdom from Russia, JW 53. Given the unreliable reception of radio signals in North Russia, however, there was always concern over whether or not the homing signal from the shadowing aircraft or submarine would be strong enough to operate the M/F transmitter without 'singing'. Russian intransigence, in any case ensured that transmissions did not start until the end of March, this particular delay being caused by the Soviet customs who had sealed up all the equipment on both sites. After additional experiments had been conducted, transmitter and receiver were handed over to the Royal Navy in a fully operational condition. Their task completed the No 80 Wing party returned to the United Kingdom arriving by sea, in the middle of May, 1943.[40]

6. See-Saw, Bernhard and Bernhardine

Meanwhile, back in the United Kingdom, a new German signal had been heard early in 1942 (although it was suspected that the transmissions had started earlier) on frequencies between 3 and 12 Mcs. These continued until the following April, then ceased. They resumed in September, when much more information was obtained. It was concluded that the H/F band signals came from a rotating aerial, but it could not be ascertained whether they were

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[39] Ibid., p.39.

[40] Ibid.

for use by aircraft or surface vessels. Results of D/F action placed the source of transmission in the Berlin/Stettin area. The device was allocated the codeword See-Saw and appeared to be in the experimental stage.[41] A countermeasure was not considered necessary at this time but, as a precaution, proposals were called for from TRE. In June, the Central Intelligence Unit reported the existence of an unusual display of aerials at Desvres, near Boulogne, approximately six miles East of Knickebein 6. It comprised two arrays one above the other, the lower being similar to a Knickebein installation, the overall dimensions measuring 40m by 40m.[42] It was allocated the codeword Windjammer and later similar sites were identified at: Bergen-Belveder in Holland, St Vaast, La Penelle near Cherbourg, Sizu-St Michael at Commana, Arcachon near Bordeaux, Pouzages at Nantes, Favieres near Chartres and Malemont at Reims. It subsequently transpired that these radio aids were to be used for the control of Luftwaffe night fighters. The German air force called the ground equipment Bernhard and the associated airborne apparatus Bernhardine.[43]

7. TRE at Swanage and Malvern; and the Sunday Soviets

With the Wehrmacht fully occupied with Russia, TRE could turn its attentions to helping Bomber Command.[44] Moreover, a number of new navigation equipments were now becoming available from TRE such as Dr R.J. Dippy's Gee, which employed a system of accurately phased pulses transmitted from the ground, and airborne RCM devices such as improved versions of Mandrel

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[41] PRO Avia 7/2044.

[42] CIU Interpretation Report No G 308, 28 June 1942, quoted in PRO Air 41/46, p.40.

[43] PRO Air 41/46, p.40.

[44] PRO Air 20/8953, p.10.

and Jostle. Window was another RCM device being developed early in 1942 by the scientist, Mrs Joan Curran. It consisted of bundles of combined metal and paper strips, cut to half wavelength, which produced a number of spurious echoes on radar screens.[45] At the same time, a detailed investigation was being conducted into the German radar system, in order to work out how best to employ the airborne jammers in an operational environment and thus obtain optimum results from the new or improved jamming equipment. TRE, however, was not working in isolation, far from it. Its very success depended on a close liaison with the domestic radio industry and with an exchange of information with the Air Ministry, including ADI (Science), and such organisations as RAE, the GPO and its Research Department, the BBC, the Intelligence Service in general and Y-Service in particular and the Admiralty Signals Establishment. None the less, it was at TRE that the fundamental conceptions were established on which future radio countermeasures were based. This strong position enabled A.P. Rowe to submit papers to the RCM Board in London not only on future policy, but also proposals concerning future technical requirements, including methods of operation.[46]

The personnel at TRE worked seven days a week and the Superintendent's unique Sunday Soviets, or open forums, were a great help to designers of equipment and users alike. Individuals, active in the RCM field and of the calibre of Lord Cherwell, Sir Henry Tizard, Watson Watt and Sir Robert Renwick somehow managed to get away from their responsibilities in London, at weekends, and hear at first-hand about current problems and help

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[45] PRO Avia 7/3618; PRO Avia 7/3619; PRO Avia 7/3620.

[46] PRO Air 20/8953, p.4.

to sort out various shortages of equipment. Moreover, many of the users of the devices being discussed, who were largely from the RAF, also attended the sessions and were encouraged to inform the assembled company about shortcomings in existing equipment.[47] It soon became obvious that it was important not only to gain the initiative in the RCM field but also to maintain it. To achieve this, long-term research was essential and TRE was well placed to achieve this vital responsibility. Swanage, however, was not the end of the story. Worth Matravers, although a purpose-built site, was not really suitable. Moreover, it was very close to the cliffs and with Bruneval in mind it was decided to move TRE yet again, this time to Malvern where, in 1942, it gratefully occupied the College buildings until the end of hostilities. RAF Defford became the home of the Technical Flying Unit (TFU) which did so much for TRE with the provision of the necessary aircraft and ground and air crews required for the installation and testing of airborne equipment, before production by industry and subsequent use by RAF Commands and others.[48] Installation at units was achieved with the assistance of TRE's Post Design Service.[49]

Often, TRE civilians volunteered to fly in these aircraft over German territory as specialist radar navigators, invariably without the advantages of any formal RAF training, and sometimes without even the benefit of honorary rank and uniform.[50] This was especially so with the airborne trials and development of Gee, and

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[47] Ibid., pp.4-5.

[48] PRO Avia 7/1603; PRO Avia 7/2685; PRO Avia 7/2686; PRO Avia 7/2687; PRO Avia 7/2688; PRO Avia 7/2689; PRO Avia 7/2690; Albert Shorrock, Airframe Fitter at RAF Defford, ed. By Colin Latham and Anne Stobbs, *Pioneers of Radar*, pp.214-216.

[49] PRO Air 20/1532.

[50] R.V. Jones, *Most Secret War*, p.265.

H2S, an advanced navigation and bombing aid, and other navigation and jamming devices. Moreover, these practices were not entirely without risk. On 7 June 1942, Halifax V9977 crashed on an H2S trials flight, killing all 11 persons on board; including most of the H2S design team and its outstanding leader Eric Blumlein. This loss delayed production.[51] During the war some seventy-one known casualties, RAF personnel and scientists, lost their lives in radar research.[52]

Summary

This chapter has argued that the Channel dash was undoubtedly a German tactical success and that it certainly caused much anguish amongst the British services, and focussed attention on the lack of co-operation between the Royal Navy and Royal Air Force. Nevertheless, for the escape to succeed as well as it did required immense effort on the part of the German authorities, which included the jamming of British radar. This had not been done before for fear of reprisal and indeed there were some, on the British side, who wished to refrain from future action of this sort on the same grounds, even after the Germans had introduced it. Nonetheless, offensive jamming had been initiated, albeit by Germany, and a watershed was thereby reached in the radio countermeasure war.

Thanks to ADI (Science) much more was now known about Germany's early warning radar system. Nevertheless, it still came as a shock to learn of the extent and range of the German system and to realise that RAF and USAAF aircraft could be under German

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[51] Colin Latham and Anne Stobbs, Ed., *Pioneers of Radar*, p.250.

[52] Ibid., p.251; Pamphlet RSA 192/10, Radar Research Squadron.

surveillance while flying over the southern half of the United Kingdom. TRE thus produced an airborne device, Mandrel, which substantially reduced the amount of early warning provided by Freya, and this was to be of great help to Fighter Command and Bomber Command during their Circus and Rhubarb operations. Another airborne device, Moonshine, also became available at this time, which multiplied the number of echoes being received on the German radar screens. Although only of use in daylight, this airborne equipment proved extremely successful in confusing Germany's defences and thus reducing RAF and, especially, USAAF losses and thus marking the beginning of RCM cooperation with the Americans.

Although most of the Luftwaffe was now engaged in the East, the Baedeker attacks and daylight raids over the United Kingdom were more than enough to keep Fighter Command and No 80 Wing fully alert. The Ruffians too, had been brought back into use after an absence of some months. A typical attack occurred on the night 8-9 May against Norwich, which has been described in some detail in order to bring out No 80 Wing's method of meeting a threat of this nature. By March 1942, Hitler had positioned strong naval forces at Trondheim and reinforced his air forces at bases further north. When the allied convoys to North Russia had started the previous December, they experienced little interference. But from January 1942 onwards, attacks by sea and air became more frequent with a consequent loss of shipping. Moreover, by the end of the month supplies for Russia started to build up in the United Kingdom for lack of ships, many having been lost and damaged due to previous German action. One of the suggestions made by the Air Ministry was to attempt, from a base in North Russia, to Meacon the German transmissions giving details of the convoy's course and speed. This was accepted and No 80 Wing was given responsibility for the setting up the equipment and handing it over in a serviceable condition for the Royal Navy to operate.

Without the facilities provided by TRE, the Royal Air Force would have been hard put to continue with the radio countermeasure war. This Establishment, or its predecessor, had provided the RAF with the Chain Home radar and Chain Home Low radar, Air Interception and Ground Controlled Interception; and now was producing a host of navigation and bombing devices together with a battery of radio countermeasures. In addition, papers were written and submitted to the RCM Board on policy, together with suggested methods of operation of individual items of equipment. It says much for the Chief Superintendent's ability that this vital work continued during the move from Worth Matravers to Malvern and RAF Defford. Before discussing the devices being produced at TRE and required by Bomber Command, however, it will be necessary to investigate the events occurring in the United Kingdom during 1943, beginning with the changes in Luftwaffe Knickebein frequencies and beam settings.

CHAPTER SIX: 1943: A YEAR OF CHANGE IN SYSTEMS AND PROCEDURES

1. Knickebein Frequencies and Beam Settings

The German air force remaining in France in the latter half of 1942 may have been small, but its commander was determined to mount a dynamic defence in the West and attack the United Kingdom as often as possible, even if only relatively few aircraft were available.[1] But worse was to follow; by the following year, 1943, Fliegerkorps IX had become terminally feeble and largely a retaliatory force, most missions being at night, although there were some sorties during the day which exploited cloud.[2] With such small numbers of German aircraft available, however, the use of bombing aids should have been essential; but the new Knickebein frequencies, employed in conjunction with the latest E.Bl.3 receiver, were not associated with operational attacks against the United Kingdom until the middle of January 1943. No 80 Wing continued to monitor closely the changes in German systems and procedures, taking jamming action against Knickebein whenever intelligence information indicated that a Luftwaffe attack was likely to follow beam deployment. No 80 Wing's policy was successful. From April onwards during 1942 much of the German signals manpower had departed for the Mediterranean and the East and time was required to train replacements. Moreover, the Luftwaffe was aware of No 80 Wing's previous success against Knickebein and thus thought had to be given by the German Signals Staff as to how best to use the new frequencies, without attracting too much RAF attention. Beam signals were in fact transmitted three

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[1] E.R. Hooton, *Eagle in Flames*, p.273.

[2] Ibid.

times during the month, but only on the night 17-18 January did the main, but greatly reduced, bomber force select a target, London, which coincided with the beam settings. The capital was chosen on this occasion for attack with some twenty five to thirty aircraft, as a reprisal for an attack on Berlin the previous night – the first for fourteen months.[3] As a result damage was caused in twenty-two London boroughs, fifty-six fires were started and seventy-eight people killed. Daylight tip-and-run raids were also carried out by FW 190 fighter-bombers, especially when combined with the use of cloud cover.

In the single month of May, the loss rate for German fighters attacking by day rose to the unacceptable figure of two-hundred-and-thirty-two, thus forcing the fighter-bombers to attack by night.[4] From January until August 1943, German signals were frequently intercepted on two frequencies simultaneously. These came from the Knickebein 6 area, but since only one transmitter array of this type had been identified in the locality, it was assumed that the signals came from the Windjammer at Desvres. During February and March, Knickebein activity remained at a similar low level and often it was difficult to discern if the beams had been used or not. This was especially so, if the timing of the German raid coincided with aircraft of Bomber Command returning to the United Kingdom. Indeed, this occurred during a small-scale raid on Plymouth on the night 13-14 February, when Bomber Command aircraft were returning from the heaviest raid carried out against Lorient. Knickebein 10 and 11 were set to intersect over Plymouth, while at the same time Knickebein 6 and 8 were

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[3] Ken Wakefield, *Pfadfinder,* pp.199-200.

[4] E.R. Hooton, *Eagle in Flames,* p.274.

laid to cross over London, where no attack developed.[5] No 80 Wing continued to monitor closely the changes in the German system and procedures, taking jamming action against Knickebein whenever intelligence information indicated that a Luftwaffe attack was likely to follow beam deployment. No 80 Wing's policy was successful and from April onwards Knickebein activity was reduced and generally only occurred by day. But during April and May, KG2 received the latest mark of Dornier aircraft, the Do 217M, and the first officially styled Luftwaffe Pathfinder Force was created, 1/KG 66. Hitherto, those units carrying out this type of work were officially known as Beleuchter or Firelighters.

August turned out to be a busy month for the British when, as usual, Knickebein 6 was prominent. On the 18th of the month, the Ju 188E made its debut over the United Kingdom during a surprise daylight attack on Lincoln, with three aircraft of 1/KG 66. Moreover, frequency changes accompanying alterations in beam settings were noted on several occasions. Unlike Ruffian operations, all this Knickebein activity was unhurried, thereby indicating to HQ No 80 Wing and the United Kingdom authorities that the Luftwaffe was conducting training sessions. Such a procedure enabled false settings to be employed by Luftwaffe signals personnel right up to the time the attacking aircraft arrived in the actual area of the selected target. This made the application of effective countermeasures difficult. For example, during a single operation on 30 August, Knickebein 6 changed frequencies three times as follows: 31.7 Mcs/359 degrees, 322.1 Mcs/296 degrees and 31.7 Mcs/359 degrees. On five separate occasions in September, however, air activity did coincide with Knickebein

[5] Ken Wakefield, *Pfadfinder*, p.200.

transmissions and beam settings, where intersection over the target could be confirmed. All the same, Knickebein beams were increasingly becoming difficult to identify because of the tendency of the Germans to extend airfield approach frequencies until they encroached on Knickebein beam standard frequencies.[6]

2. A New Use for Knickebein

Photographic evidence obtained in June 1943, of lattice masts in the vicinity of Knickebein 1, 3, 5, and 11, seemed to indicate that some form of modification was taking place to this device. Lines joining the centres of aerial arrays to the corresponding masts passed through Edinburgh, Hull, London, and Bristol.[7] Intelligence then revealed that Knickebein beams were not being set over targets, but were being used in conjunction with Elektra transmissions to establish turning points some twenty-five to fifty miles off the English coastline, out of Aspirin range. Something similar had occurred previously when aircraft using M/F beacons had selected similarly placed turning points beyond the effective range of Meacon transmitters. The use of Knickebein beams when no raids took place, together with the changes to frequencies and settings, kept No 80 Wing aware of the high potential threat posed to the United Kingdom by the Knickebein system as a whole. This state of affairs, together with the growing danger of Benito, later led to a complete change of jamming policy. Meanwhile, the numbers of high-powered jammers becoming available to No 80 Wing had been steadily increasing, especially of the TU4 type of transmitter. The prototype had in fact been designed in 1941 by TRE for

[6] No 80 Wg. Signal RX 921 quoted in PRO Air 41/46, p.43.

[7] CIU letters MDM/S 1246/2/G dd. 17 January 1943, 29 January 1943 and 31 March 1943, quoted in PRO Air 41/46, p.44.

specialist RCM purposes, within the bands 27-100 Mcs, complete with many variable features, enabling it to be used universally against any of the known devices within the band. Thus by January 1943, when the new Knickebein frequencies came into use, additional jammers could be instantly made available; the situation being helped by the previous defeat of the Ruffian menace. HQ No 80 Wing, faced with the rising Knickebein threat, together with that posed by Benito, decided to establish all TU transmitters, with universal facilities, in the Knickebein and Benito Bands.[8]

3. The Worrying Increase in Benito

Despite the loss of confidence in Benito felt by many German aircrews, largely brought about by No 80 Wing's successful countermeasures, the number of Benito ground stations actually began to increase. By July, the following stations and aerial arrays were known to be in existence: Stavangar (20), Cassel (2), Boulogne (6), St. Valerie (3), Cherbourg (9) and Commana (2). Beam and range signals were also heard from Montdidier, but it was thought that these were only intended to assist crews of Benito aircraft to make their approach. This increase in the Benito programme forced No 80 Wing to contemplate a complete reorganisation of countermeasures, involving the layout, location and method of employment of all appropriate jammers.[9] A critical examination indicated that an additional fourteen Domino stations would be required to meet the threat posed, each with its own sophisticated equipment and highly trained crews. Neither was likely to be available in time. In May therefore HQ No 80 Wing was forced to

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[8] PRO Air 41/46 p.44.

[9] Ibid. p.46

adopt a policy of crude, or area, jamming confined to Benito Communications Channels, and to employ existing transmitters for this purpose. The decision by HQ No 80 Wing came at an awkward time; other German systems such as Knickebein, and Windjammer, also had to be considered. [10]

The change in policy was put into effect immediately, but it involved some risk; especially as it required a redistribution of transmitter assets which followed the change in policy, with in many cases the erection of one-hundred-and-five-foot aerial towers. The subsequent movement of equipment and the reorganisation of HQ No 80 Wing's Control Room was completed as rapidly as possible, although the last of the twenty-four towers was not put in place until the spring of 1944. A change in Benito procedure was confirmed when the crew of a single German aircraft was shot down and subsequently interrogated.[11] In order to avoid 80 Wing's countermeasures they had been briefed to navigate by Dead Reckoning on a time basis and then fly towards a pre-selected reference point, where the Benito beam crossed the United Kingdom coastline. The beam was then timed to come into operation at this juncture, to be followed some five minutes later by the ranging transmissions. In spite of all these changes, however, use of Benito remained at a low level. At first, the new Benito signals were used for training and testing purposes and the earliest operational use was thought by HQ No 80 Wing to be on the night 7-8 February 1943. A month later a force of thirty aircraft attacked an area in the South of England, centred on Guildford. But it was not until May 1943 that the scale of testing and training and the

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[10] Mins. AM Mtg. (D. of Tels.) 4 May 1943, quoted in PRO Air 41/46, p.46.

[11] ADI(K) Report No.263/43, quoted in PRO Air 41/46, pp.46-47.

building up of the new Benito organisation was able to be contrasted with the small amount of its actual operational use.[12]

4. Night Attacks, Fighter-Bombers and Cigarette

As we have seen prior to April 1943 tip-and-run raids by day had been conducted against targets in the South and Southeast of England by FW 190 aircraft. After suffering disastrous losses in April and May, however, these fighter-bombers were employed in delivering bombs by night, during the full moon period, on London and the Southeast. Obviously the crews concerned had to be given some form of navigational assistance, if any degree of accuracy was to be obtained. This was achieved by providing the normal aircraft transmitter/receiver FuGe 16 (38-42 Mcs) with a tone generator which could be used to modulate the transmitter. This enabled a fix to be obtained by a ground station. Two control stations were used, Cassel and Poix, the Luftwaffe signals personnel directing the aircraft involved to the approximate target area by passing the vector and flying times in plain language and giving an executive order to release bombs. Similarly, navigational assistance was also available on the return legs.[13] On the night 16-17 April 1943, twelve FW 190 aircraft mingled with RAF bombers returning from raids on Pilsen and Mannheim, and were plotted over the Eastern Home Counties and the Greater London area.[14]

German records indicate, however, that forty-seven fighter-bomber aircraft were despatched on the first night attack against

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[12] PRO Air 41/46, p.47.

[13] Ibid., pp.47-48.

[14] Ibid.

London, and five failed to return.[15] The Luftwaffe aircraft caused little damage; two of them landed at West Malling in Kent and two crashed, all due to Meaconing action. At least four of the German aircraft were controlled from the ground at Cassel using 41.4 Mcs. R/T was used and English names employed as callsigns, plain language being used throughout the operation. During the following month fighter–bomber R/T communications were heard on 38.5 to 42.3 Mcs., control being shared between the ground stations at Cassel and Poix. The former acted as control and the latter homed the aircraft to their base. For these operations, control used frequencies from 39.3 to 41.4 Mcs and the aircraft 39.3 to 40.9 Mcs. For Homing purposes a common frequency was employed, 42.1 Mcs.[16] In contrast with the defensive phase, when disaster was often narrowly arrested, British countermeasures now had a clear supremacy.

5. A Response to the Fighter-Bomber Threat

Ground Cigar was a British R/T jammer, used in the 38-42 Mcs band, which had already been developed for use against the control of German night fighters (See Figure 15). With the knowledge and experience so gained against the night fighters, it was advantageous to modify the equipment to combat the new threat posed by the fighter-bombers. The new countermeasure was called Cigarette.[17] But many of the transmitters already held by No 80 Wing, such as Aspirins, Bromides and Benjamins were also capable of covering these frequencies and thus, during April, arrangements were made by Addison to use some of them as an

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[15] E.R. Hooton, *Eagle in Flames*, p.274.

[16] HQ No 80 Wg Signal Rx 785 quoted in Air 41/46, pp.47-48.

[17] PRO Air 41/46, pp.48-49.

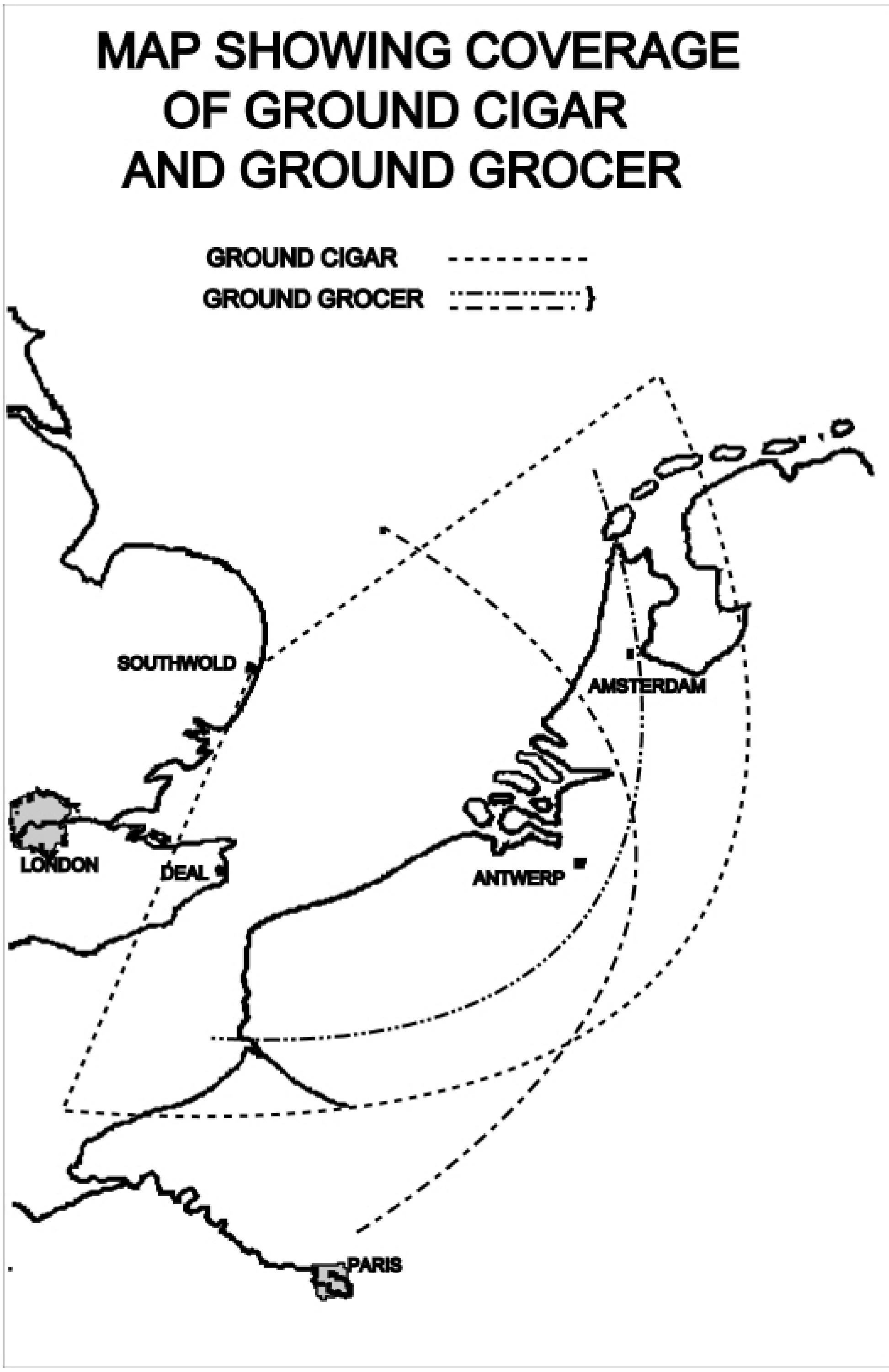

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Figure 15
Ground Cigar

interim measure, in order to jam the control instructions being passed to the German aircraft. While modifications were being implemented, noise generators were provided to modulate certain of these transmitters thereby providing optimum jamming of speech. The potential Cigarette jammers were then fitted with Marconi-Stillo reproducers to feed German speech or similar modulations to the transmitters. In addition to a T.1298 transmitter at Ide Hill, the Alexandra Palace Television Transmitter was also modified to include the fighter-bomber frequency band of 38-42 Mcs, with a Marconi-Stillo tape reproducer to provide the modulation. The SWB 4 transmitter at Harpenden also had its frequency range extended from 42-48 Mcs to 38-48 Mcs and was available for operation on 28 May 1943. By the end of July all USB, SWB 8 and SWB 4 transmitters had been modified to cover these frequency bands without the necessity of a major coil change. The use of R/T for this purpose by the Luftwaffe, however, quickly waned since the psychological effect of jamming the control instructions being passed to the Luftwaffe pilots greatly outweighed the few occasions when No 80 Wing were unsuccessful. So much was this so, that in June 1943, the last month of fighter-bomber attacks against the United Kingdom, vector information was confined to homing instructions, when Luftwaffe aircraft were out of range of RAF jamming devices.

6. M/F Beacons, Elektra, Sonne and Consol

The system of German Medium Frequency beacon rotas described earlier continued until the spring of 1943 when, on 1 March 1943, the German Air Force introduced a completely new scheme. The principal beacons were now divided into fourteen beacon groups, each consisting of three sites. The frequencies in use were then interchanged at fifteen-minute intervals, the frequency numerals being retained as call signs. In April, the singular number of transmitters was increased at each site to three at the four coastal groups; by July some groups even consisted of four sites each with three transmitters. Fortunately for No 80 Wing this new departure considerably simplified the allocation of Meacons, since a given frequency was employed in the same area. Fortuitously, a reduction in Splasher traffic (a Bomber Command – USAAF navigation beacon) unexpectedly produced several transmitters that could be used for Meaconing purposes. Existing Meacon sites and the RAF Y-Service then reported a marked reduction in the strength of Luftwaffe beacon signal strengths, rendering Meaconing more difficult and on occasions impossible. Around February 1943, the German Elektra organisation, which by now had expanded to some six stations, was revolutionised by the introduction of Sonne. This consisted of a fan of Elektra beams sweeping in azimuth, which by a simple counting process and reference to an appropriate chart, enabled an operator to determine bearings from a transmitter to an accuracy of between 1/3 and 1/6 of a degree at intervals of two minutes. This was quite an advantage over Elektra, which was only accurate on the equi-signal lines, in contradistinction to Sonne which provided a true navigational picture any where within its area of cover.

The first Sonne signals were detected in the United Kingdom in February 1943 coming from the area of Brest, E6, to the south of E4 at Morlaix, and these were followed in April by a new station in Holland, Sonne 5. During this same month E1 at Stavanger converted to Sonne 1, and another new station, Sonne 15, on 303.2 Kcs, was established in Northwest Spain, near Lugo, notwithstanding the niceties of Spain's neutrality. The British authorities had been aware of the German threat to Spain since the summer of 1940, and knew that General Franco continued to evade committing Spain to the German cause.[18] From January 1941 onwards, it became increasingly unlikely that Spain would agree to the entry of German forces. Nevertheless, the possibility of German occupation of the Iberian Peninsula and Britain taking action was kept under review.[19] In view of this situation and the fact that often warning of attack against the United Kingdom was obtained from Sonne stations, changing to Elektra immediately prior to a raid, the British did not make an issue of the breach of neutrality. Three further stations were then erected in September 1943, including another in Spain, near Seville. Subsequently, No 80 Wing took Meaconing action against all Elektra and Sonne transmissions, within range, that could be used by the German Air Force during attacks against targets located in the United Kingdom, except those required by Coastal Command.[20] The Royal Air Force was especially impressed with the accuracy of Sonne. It was thus in this way that the British came to use a German navigation system, which was known in the RAF by its British name of Consol. Before it could be introduced into Coastal Command, however, special charts, had to be prepared for the crews concerned by HQ No 80 Wing. In the event, only the transmitters located at Brest, S6, and the one in Northwest Spain, S15, were wanted and consequently, arrangements were made by No 80 Wing not to Meacon these particular German transmissions.

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[18] Ernst Klink, 'The Military Concept of the War against the Soviet Union' in Research Institute for Military History, Potsdam, Germany (eds.) *Germany and the Second World War:* Vol. IV, *The Attack on the Soviet Union,* p. 277

[19] F.H. Hinsley, *British Intelligence in the Second World War,* Vol.1, pp. 256-257

[20] ADI(K) Reports SRA 4950 dd.6 June 1943, SR draft 3512, dd.6 June 1943, quoted in PRO Air 41/46, pp.49-50; F.H. Hinsley, *British Intelligence in the Second World War,* Vol.3, Part1, pp. 576-577

7. The Anti–Jamming Unit

In the years prior to 1939 so much priority was given to erecting and installing the Chain Home air defence radar, that there was little time for anti-jamming circuits either to be considered or to be inserted into the equipments. None the less, it was always realised that there would be the danger of this sort of German interference, as indeed did happen during the successful Channel Dash by the German Navy in 1942.[21] Thus the RAF found itself in the position of countering German jamming by stopgap methods in order to keep the radar chain in operation. It soon became obvious that, since the type of jamming varied, any corrective action taken would always fall one step behind Germany. Long-term research was clearly going to be necessary if a coherent anti-jamming policy was to be achieved. Obviously, this could not be done all the time that the A-J unit at TRE was being subjected to current demands for anti-jamming equipment. It was therefore decided to establish a special Anti-jamming unit to conduct the fieldwork, which would concentrate hard on current German interference practices. This arrangement permitted the Research Establishments, TRE, RAE, and ASE to focus their attention on producing radar circuits, which, it was hoped, would be immune from jamming or, better still, to devise a universal anti-jamming device. The new unit became effective in March 1943,[22] at Radlett, under the administrative control of HQ No 80 Wing, and was given control of the existing J Watch, with its special monitoring stations based along the south coast. The results obtained were quite inconsistent with the degree of effort expended in following this

[21] PRO Air 41/46, p.52.

[22] Ibid.

particular policy. Nevertheless, experience was gained and much useful knowledge gleaned about German jamming techniques, all of which was used to good effect in the design of future anti-jamming circuits.

Summary

The numbers of German aircraft based in the West in 1943 were small compared with those of previous years, but many of them were the latest models such as the Do 217M, the Ju 188E and the powerful and very fast FW 190 fighter and fighter-bomber. Moreover, the Luftwaffe intended that these aircraft should take the offensive against the United Kingdom whenever it was practicable to do so, and thus force the RAF to maintain strong, but wasteful, fighter patrols. There were other problems, however, for the Luftwaffe, which included the number of casualties sustained by their fighter-bombers during operations over England and the need to reinforce the Mediterranean area. Due to an increasingly effective RAF night fighter force and the ever-effective Meacons of No 80 Wing, significant damage to ports and docks in the United Kingdom was avoided for the time being. Moreover, new equipments and changes in frequency required much extra training for the Luftwaffe personnel involved and thus Knickebein was not used extensively in the early part of the year. Often attacks were planned to coincide with returning Bomber Command aircraft, as occurred during the raid on Plymouth on 13-14 February. By April, the use of Knickebein had been much curtailed and was restricted to daylight use only. This changed in August, however, when there was a flurry of activity accompanied by many changes of frequency. False settings of beams prior to an attack now became a common feature of the German tactics, making the application of radio countermeasures extremely difficult. On top of this, No 80 Wing found it increasingly difficult to identify

Knickebein beams as German airfield approach frequencies were extended and started to encroach on those employed by Knickebein.

In spite of the loss of confidence in Benito experienced by some Luftwaffe crews, the number of Benito sites started to increase in May, and this expansion caused HQ No 80 Wing some apprehension. There simply were not enough Domino sites available for such an increase and thus crude, or area, jamming had to be adopted. To be successful, this new policy required much reorganisation, movement of transmitters, construction of new aerial towers and changes in HQ No 80 Wing Control Room. All went well and the new policy was adopted quickly and successfully. Intelligence information then revealed that there had been a change in Benito operating procedures. In order to avoid the worst effects of British countermeasures, German crews had been required, for some time, to navigate by D/R until they reached a pre-arranged point on the English coastline, whereupon the beam would then be switched on, enabling it to be followed to the target area in the normal way. Starting in January 1943, the Luftwaffe had met with some success with their tip-and-run raids conducted by FW 190 aircraft in daylight against targets situated in the United Kingdom, especially when combined with use of cloud cover. A number of German casualties had been sustained during the course of these particular operations, but then in the single month of May, the loss rate of the fighter-bombers rose to an unacceptable figure. This forced the Luftwaffe in future to attack by night with the aid of a sophisticated means of R/T control using plain language. No 80 Wing had previously used a jammer, Ground Cigar, against German night fighters and gained considerable experience in its use. By modifying this equipment, it was found possible to meet the threat posed by the fighter-bombers. The new jammer called Cigarette was able successfully to interrupt the vital control instructions, which emanated from Cassel and Poix, and shortly the vogue for controlling fighter aircraft by this means ceased.

February 1943 not only saw an expansion of the German Elektra navigation system, but also the introduction of the much more accurate Sonne. No 80 Wing was able to take successful Meaconing action against both systems, making an exception for the Sonne beacons that Coastal Command wished to use. A month later, and in order to avoid the worst effects of Royal Air Force Meaconing, the German Air Force, on 1 March 1943, introduced a new and complicated scheme for their M/F beacons. The following month the number of associated transmitters was also increased. HQ No 80 Wing followed all these changes with great interest and noted a marked reduction in beacon signal strength that, of course, rendered Meaconing more difficult. The year as a whole was marked by a greater use by the Luftwaffe of electronic aids, especially Knickebein, Consol and Sonne. It is now time to find out how the new navigation aids and radio countermeasure devices coming from TRE were helping Bomber Command and what the Luftwaffe's reaction was to this greatly enhanced threat.

CHAPTER SEVEN: 1942 AND 1943: THE RCM YEARS

1. Bomber Command's Dilemma

Despite the successful activities of No 80 (Signals) Wing, an Air Ministry Unit, Bomber Command was not in much better shape at the end of 1941 than it had been at the beginning of the war, especially in the methods being used for navigation, finding the target and bombing; disadvantages which were mentioned in Chapter 1. Indeed, earlier in the year Professor F.A. Lindemann, later Lord Cherwell, Scientific Adviser to the Prime Minister, had expressed strong doubts about the accuracy of the claims by Bomber Command that they were finding and hitting their targets as claimed in the, almost nightly, BBC communiqués. Accordingly, Professor Lindemann started an inquiry, which resulted in cameras being placed in aircraft to take photographs at the point of bomb release. His Secretary, Mr D.M. Butt studied these photos at length in the summer of 1941; these showed that over the Ruhr, only one tenth of the bombers was within five miles of the intended target.[1] The Butt Report conclusively demonstrated that the majority of Bomber Command crews could not find and bomb a precise target by night.[2] A new bombing policy thus became inevitable and a decision was taken at the end of 1941 to attack areas of Germany, rather than precise targets. As casualty figures began to rise, the debate about bombing focussed attention on the need for radio aids, along the lines used by the Luftwaffe. These instruments were an absolute necessity, even though their use might entail

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[1] Butt Report to Bomber Command, 18 August 1941, App.13, quoted in C. Webster and N. Frankland, *The Strategic Air Offensive Against Germany 1939-1945*, vol.1, p.178; Max Hastings, *Bomber Command* (Pan Books, 1995), p.108.

[2] C. Webster and N. Frankland, *The Strategic Air Offensive Against Germany 1939-1945*, vol.1, pp.179-180.

disclosing the presence of the RAF bomber stream. The realisation that our navigation and bombing was inaccurate undoubtedly changed Bomber Command's views about the use of radio navigational devices.[3]

The Air Staff became convinced that existing methods of air navigation, used during World War One, such as Dead Reckoning and Astro navigation were no longer good enough. Radio aids, along the lines used by the Luftwaffe, were now an absolute necessity.[4] But there was more to the Report than that. The whole of the bomber offensive now started to be questioned, especially by the Army and the Royal Navy. Was there a need for Bomber Command at all? Could the aircraft concerned be better employed by the Army, dropping parachutists? Or perhaps be allocated to Coastal Command to fight the Battle of the Atlantic, under the operational control of the Admiralty? However, whatever future lay in store for the Command, the critics, and there were many, had to remember that it was the only force available, at the time, which could carry the war to the German heartland. The Army and the Royal Navy certainly could not. Dr R.J. Dippy of TRE had, shortly before the war, developed a navigational device based on pulsed radio signals, which had been not taken up at the time due to the pressure to install the Early Warning chain.[5] But in any case, such was the arrogance displayed at the time by Bomber Command; it would not have wanted such assistance at that stage. After the Butt Report, however, Bomber Command was more amenable to the use of such aids and Gee, as it became known, was more

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[3] R.V. Jones, *Most Secret War*, p.210.

[4] Ibid.

[5] Colin Latham and Anne Stubbs, *Radar*, p.6.

acceptable. Three ground stations were required in the United Kingdom for this device, widely spaced, which transmitted three synchronised pulses.

The navigator, using his on-board Gee box, then measured the difference in time of the arrival of the signals thus enabling him to establish the aircraft's position to within five miles. Gee was not a lot of use as a bombing aid, as at first had been hoped; but for measuring wind velocities, establishing turning-points and finding base on the return leg it was most successful – and popular too, with the aircrews concerned. It was first used experimentally but prematurely, over Germany on 13 August 1941, which led to its early jamming by the Luftwaffe. Its operational debut came seven months later on the night 13-14 March 1942, during a raid on Cologne. This raid was considered to be five times more effective than the average of recent attacks on this target.[6]

On 23 February 1942, Sir Arthur Harris was appointed AOC-in-C, Bomber Command, on his return from Head of the RAF Delegation to the United States; his predecessor at High Wycombe, Air Marshal Sir Richard Peirse, being sent to the Far East. The force at his disposal was a modest one comprising, three-hundred-and-seventy-eight serviceable aircraft, complete with crews. Of these, however, only sixty-nine were heavy bombers, the remainder falling into the medium and light categories.[7] Sir Arthur, with the whole future of his command at stake, immediately set about finding ways to concentrate his bomber force when operating over German-held territory, in order to protect aircraft and crews as much as possible and to ensure the destruction of the target.

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[6] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.248.

[7] PRO Air 14/1962, Despatch on War Operations, the Force Available, p.8.

In this aim, he was to be helped considerably by the introduction of the first of the new radio devices, Gee. Even at this early stage, the new Commander-in-Chief hoped there would come a time when he would be able to place one hundred aircraft per hour over a German target.[8] This was not long in coming. On the night 3-4 March 1942, Bomber Command successfully attacked the Billancourt Renault factory, near Paris, known to be producing war material for the German war effort. There was no question of not finding the target that night and, in the process, a number of records were broken: the greatest number of aircraft sent to a target, so far in the war, was surpassed, two-hundred-and-thirty-five; the greatest concentration over the target, was surpassed with one hundred and twenty-one per hour, even though Gee was not used because of problems in production; a mass use of flares for illumination purposes and selection of the best crews to open the raid; heralding perhaps the beginnings of a British pathfinder force. By the end of the month, the old German City of Lübeck was in flames, 1,000 dwellings being completely destroyed and over 4,000 partially, with a loss rate to Bomber Command of some 5½ per cent.[9] A rate which was acceptable on this occasion, but not sustainable in the long term. Then came four notable raids on Rostock, the home of the Heinkel aircraft works. They commenced on the night 23-24 April 1942, and the cumulative effect caused much devastation, some 60 per cent of the old city being burned out.[10]

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[8] Sir Arthur Harris, *Bomber Offensive* (Collins, 1947), p.85.

[9] Cajus Bekker, *The Luftwaffe War Diaries*, p.306.

[10] Ibid.

While Bomber Command was carrying out other attacks against Germany, Air Marshal Harris was drawing up plans for a masterstroke, which required him to draw heavily on all his reserves of manpower and aircraft. These were for the unique thousand-bomber raids, which took place against Cologne on 30-31 May and Essen on 2-3 June. Although the second attack was not as successful as the first, Bomber Command casualties sustained on both raids remained at what was considered an acceptable level, around four and a half per cent, although the trend was rising. The view within the Air Ministry was that losses below 6 per cent were sustainable, at least for a time; a rate of 7 per cent was not.[11] Sir Arthur Harris had made his point: Bomber Command could, after all, find a target in the dark and hit it hard. After his first three months in command there was less talk of Bomber Command being disbanded and its aircraft being used for other purposes under the army and navy.

2. Kammhuber and German Air Defence

Upon the outbreak of hostilities, Germany had little or no organised air defence system. Why should they have had, when they possessed the most powerful air force in the world? The Germans were as arrogant as Bomber Command although they were aware of the Royal Air Force, and its strengths and weaknesses.[12] They did have a chain of Freya early warning stations, stretching from Denmark to the Swiss frontier, but

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[11] C. Webster and N. Frankland, *The Strategic Air Offensive against Germany 1939-19*45, vol.1, pp.419-420.

[12] Derek Wood, *The Narrow Margin*, pp.64-65; Horst Boog,'Air defence in the German Air War Doctrine and the Build-Up of German Air defences in Peacetime' in Research Institute for Military History, Potsdam, Germany (eds.) *Germany and the Second World War: vol. VI, The Global War*, p. 482.

without a central control.[13] Things began to change, however, when the United Kingdom refused to accede to Hitler's demands. Indeed far from giving in, the British government decided to attack the German heartland with what bomber force it possessed at the time. Hitler then decided that, perhaps after all, such an organised air defence system was going to be required. Goering promptly appointed Colonel Joseph Kammhuber to make good the omission and institute a proper air defence of the Third Reich. From that time onwards the German air defences continued to improve on the situation where, in the early days, pilots took off on receipt of warning from the Freyas situated on the coast, and orbited a radio beacon until searchlights illuminated the RAF bombers.[14] There were, however, problems of friendly fire with this system, and thus during 1941 the searchlights were moved away from the towns to a belt running from Schleswig in the north to Liege in Belgium, through which all Bomber Command aircraft would have to pass to reach their targets. In August Kammhuber was rewarded for his efficiency and promoted to General of Night Fighters.

He also introduced a method whereby night fighters patrolled in a number of boxes, or areas of sky, positioned in front of the searchlights, until required.[15] Each box was allocated one Freya for early warning and two Wurzburg radars, one for tracking the bomber and the other for directing the night fighter on to its prey. Thus two attempts at interception were possible, one with the aid

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[13] Horst Boog, 'The Beginnings of the Strategic Bombing War by the Royal Air Force, the German Air defence, and the American Preparations for Air War up to the end of 1941' in Research Institute for Military History, Potsdam, Germany (eds.) *Germany and the Second World War: Vol. VI, The Global War*, p.523; Gebhard Aders, *History of the German Night fighter Force 1917-1945*, p.22.

[14] Alfred Price, *Instruments of Darkness*, p.63.

[15] Gebhard Aders, *History of the German Night fighter Force 1917-1945*, pp.34-35.

of the radar in front of the searchlights and one after, using the illumination of the searchlights to assist interception.[16] At the same time experiments were being conducted with Dr Ruge's AI radar, which was being installed in a few of the Bf 110, the standard night fighter aircraft, in the form of FuG 202 Lichtenstein B/C.[17] It was with this equipment that Ludwig Becker achieved an early victory against Bomber Command on 10 August 1941.[18] But it was not until the following November that this airborne interception (AI) equipment was really ready for use, when the Luftwaffe Technical Office agreed dates for the arrival of the first of 40 sets. Even then, although deadlines were set for delivery, slippage was considerable and the first four sets were not installed in the aircraft of 11/NJG 1 until February 1942.[19] The Kammhuber line was also strengthened in the winter months with the Giant Wurzburg, and by Mammut and Wassermann improved radars in the spring of 1942.

In this way, General Kammhuber established the foundations of an efficient and effective defence organisation, which was to expand over the months to come, especially after the raid on Cologne, and develop into a formidable Night fighter Force and test Bomber Command to the limit. Josef Kammhuber's reaction to the successful RAF attacks in March, April and May was to improve his fighting technique by enlarging his night fighter defence zones to cover much more of Holland, Belgium and Germany than hitherto and acquiring more and more night fighter Gruppen in order to

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[16] Ibid.

[17] Ibid.,pp.40-43.

[18] Ibid.

[19] Ibid.

strengthen the German defences.[20] In addition, new methods of control were devised, which enabled two or even three night fighters to operate in a single zone. This was a weakness of the previous system and one that Sir Arthur Harris fully exploited by concentrating his force in time and space. This is exactly what the latter did on the night of 25-26 June, when over a thousand British aircraft attacked Bremen. The results were not as devastating as at Cologne, but much better than the second thousand bomber raid to Essen on the night 1-2 June. Nevertheless, Bomber Command lost forty-eight aircraft that night, (the German records say forty-nine), and this figure represented a high of 5 per cent.[21] Losses continued to rise until the end of the year and this trend could only encourage General Kammhuber and the German air defence authorities.

3. Airborne RCM – A Start

Indeed, the rate of loss of Bomber Command aircraft at the beginning of 1942 had already started to rise, and much of this was due to the efficiency of Kammhuber's defences, brought about by the introduction of radar assisted searchlights, guns and air interception.[22] Although somewhat late in the day, it is not surprising that the Operational Research Section (ORS) at High Wycombe published a paper in August 1942 on the advantages of employing Radio Countermeasures.[23] It disclosed that during the previous two months the overall wastage of bomber aircraft had

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[20] Cajus Bekker, *The Luftwaffe War Diaries*, pp.306-307.

[21] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.281; Cajus Bekker, *The Luftwaffe War Diaries*, p.307.

[22] PRO Air 14/1962, App."E", pp.133-134.

[23] Ibid.

been 5.6 per cent of sorties and, of this total, a minimum of 30 per cent and a maximum of 60 per cent were due to radar defences.[24] It was considered that the use of countermeasures could reduce the loss rate by one-third, which would, in effect, mean that the scale of bomber effort could be increased in the same proportion. In addition, there could probably be a further increase in the effectiveness of Bomber Command's attacks consequent on the reduced efficiency and deterrent effect of German defences in the target area. The ORS paper concluded that the highest priority should be given to the development of all possible countermeasures against German radar.[25] At the time of course, the benefits from radio countermeasures were well known and had been urged on Bomber Command by TRE and others who were concerned at the growing loss Bomber Command was sustaining as a result of improved German defences.

There still seemed to be, however, an innate reluctance on the part of the United Kingdom Authorities to start offensive jamming for fear of retaliation. Radar was considered to be a British invention and so sensitive that the British would go to almost any lengths in order to avoid compromising it. The thought of the Chain Home and Chain Home (Low) radar being jammed by the Luftwaffe was an anathema to the Air Ministry in general and Fighter Command in particular. One aid, however, was already in use and it involved a special switch in the standard Identification, Friend or Foe (IFF) equipment. Aircrews previously had claimed, in late 1940

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[24] Ibid.

[25] PRO Avia 7/1853; PRO Avia 7/1879; PRO Avia 7/1880; PRO Air 14/1845; PRO Air 16/590; PRO Air 20/1454; PRO Air 20/1455; PRO Air 20/1463; PRO Air 20/8963; PRO Avia 7/2401.

and in 1941 that advantage could be obtained by operating this equipment when coned by German radar controlled searchlights. Consequently, the equipment was modified in July 1942, to enable them to do this, despite the lack of scientific evidence and hence the reluctance to agree to such a modification on the part of ADI (Science). This was Shiver and it was set on the intermediate frequency of Wurzburg. In August, following the publication of the ORS Report, the whole question of the use of radio countermeasures was reopened when a letter was sent to the Air Ministry requesting that Bomber Command be furnished with appropriate airborne jamming equipment, as speedily as possible.[26] It was known that TRE were developing a number of RCM devices and what was now required was the authority to employ them. This initiative came none too soon. Gee was suspected of being jammed by the Luftwaffe on the night of 6-7 August and confirmed three nights later when Osnabruck was attacked.

In spite of the success of the attack on the Renault factory near Paris on 3/4 March 1942, when flares were used on a massive scale, Sir Arthur Harris was not in favour of a Pathfinder Force being formed, fearing an adverse effect on his command of denuding formations of their best units. He much preferred each Group to develop its own specialised method of finding and marking targets, which later on some of them did. After considerable, and sometime acrimonious, discussion between the Air Ministry and Bomber Command, the Air Ministry overruled Harris. The Pathfinder Force (PFF) was formed on the 15th of August 1942, and eventually became No 8 Group, under the

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[26] PRO Air 14/1962, p.133.

command of AVM Donald Bennett; the subsequent actions of this formation improved the illumination and marking of German targets by the use of flares for the benefit of Main Force aircraft.[27]

Meanwhile, TRE were busily developing two new navigation and bombing systems. One was Oboe an accurate bombing aid, possibly the most accurate of the war, developed by A.H. Reeves. It involved a tracking station sending out pulses to an aircraft with a transponder. The strong return signal enabled the aircraft to be controlled to fly at a constant distance from the 'Cat' station. Another station, the 'Mouse' sent out pulses on the same frequency but at a different repetition rate, thus enabling the range and velocity of the aircraft to be measured and a bomb release signal to be sent. Oboe thus used some of the technology of Y-Verfahren, but was a more accurate system. The other was H2S, which was advanced airborne centrimetric radar, providing a rough outline of the ground below on a plan position indicator screen. At the time it was brought into service there was no Luftwaffe equivalent. In this connection, No 109 Squadron, which earlier had done so much sterling work for No 80 Wing, acquiring much expertise in the art of beam flying in the process, was transferred to No 8 Group where, as a founder member of the RAF Pathfinder Force (PFF), it was subsequently employed as an Oboe unit in August 1942.

A long pause then ensued, for it was not until 6 October 1942 before another meeting was held at High Wycombe to consider the problem. This meeting was held under the Chairmanship of the Senior Air Staff Officer, Air Vice Marshal R.H.M.S. Saundby. It was well attended, as indeed it should have been, and included Sir Henry Tizard, the Director of Bomber Operations, the Director of

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[27] Ibid., pp.10-11.

Signals, the Command Signals Officer, Command Operational Research Section and other representatives of the Air Staff. Four likely uses for RCM were then considered: to focus on the German Early Warning System then operating on 120-130 Mcs, the components being the Freyas, with a range of 100 miles, which were later reinforced in the coastal areas by the improved, longer range Chimneys and Hoardings; to interfere with the close control of the German night fighters by jamming the two Wurzburg radars operating on 570 Mcs and the associated Freya, at the German GCI stations; to concentrate on the HF R/T communications link between GCI and aircraft, in the 3-6 Mcs band, to interfere with the Luftwaffe night fighter's AI working on 490 Mcs. At the end of the discussions, the Meeting recommended: the continued use of Shiver, in spite of its lack of scientific credence; an airborne jammer to be produced for use against Wurzburg; airborne Mandrel to be employed against Freya, in the 120-130 Mcs band, two aircraft in each Squadron to be so equipped and No 80 Wing's ground Mandrels at Hastings and Dover, to be used in conjunction with the airborne barrage.[28]

Because some aircraft were already using Shiver, Bomber Command was able to introduce this device immediately throughout the bomber force. Airborne Mandrel took a little longer, and was brought into use in December 1942. Moreover, early in the same month Tinsel was introduced.[29] This was a device designed to interrupt the communications link between the German GCI station and its night fighters. It was achieved by modulating the noise from the aircraft engines, using the standard aircraft wireless

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[28] PRO Air 14/1962, p.134.

[29] PRO Air 20/1492, p.7.

transmitters. Each Wireless Operator was required to search a range of 150 Kcs between 3-6 Mcs for German R/T transmissions and then to transmit in the normal way. Tinsel and Mandrel were introduced together in December 1942, with the result that it was difficult to assess the effectiveness of either device. Certainly neither caused major disruptions to the German night fighter organisation, but the RAF Y-Service did confirm that these devices became a minor, but constant irritant to the Luftwaffe. Moreover, they were the first elements in a campaign that was to grow considerably larger over the next year or so. Their debut coincided with a start in the fall of the Bomber Command casualty rate. But weather too played a part in this reduction and also the fact that the sheer weight of numbers of bombers, with Oboe and H2S coming into service, had started to swamp the night fighter boxes, thereby interfering with the Luftwaffe's interception process.[30] It is difficult to conclude that these first airborne countermeasures led to reductions in the casualty rate, but at least a start had been made and Bomber Command was now firmly on the learning curve.

In January 1943, Sir Arthur felt that, with an increase of aircraft to his Command, especially the Lancaster, he was ready to start the real offensive. He possessed Oboe, which was limited by range to the Ruhr, and H2S for target-finding throughout Germany, and had permission to use the available radio countermeasures. He set his sights on Berlin, and indeed attacked it several times during the month. Because it was well beyond Gee and Oboe range, and H2S was not quite ready, the marking was inaccurate. Then came Hamburg at the end of the month when H2S was used for the first time on operations. Again the marking

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[30] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.335.

was scattered; obviously the navigators were going to require time to get used to this new navigation and blind bombing device. Eleven days later they did get it right, when during a raid on Wilhelmshaven, sky marking by H2S was most accurate and the following main force bombed accurately. Essen was then attacked on the night 5-6 March 1943 when the Mosquitoes of No 8 Group, the Pathfinders, employed Oboe. The loss rate was 3.2 per cent, but the trend was about to move in an upward direction, as Germany's air defences further improved.

In April, when the RAF Y-Service reported hearing German night fighter communications on the new frequencies of 38-42 Mcs, in the VHF band, a ground transmitter had been set up at Sizewell, in Kent, to deal with the problem, and given the name Ground Cigar.[31] It came into operation on the night of 30 July 1943 but its effect was so powerful it obliterated most, if not all of the German R/T upon which the Y-Service depended for it information. The Admiralty also objected, but Bomber Command, in most cases, was allowed to have such support, but only when bomber operations were in progress. Ground Cigar's one drawback seemed to be its short range, which was restricted to one-hundred-and-forty miles. With Mandrel, however, it was hoped to curtail the amount of early warning obtained by the Freya radar coastal stations from about one hundred miles down to twenty-five. German Inland radar, however, would be affected to a lesser extent. Thus it was more difficult to ascertain just how effective Mandrel really was. The answer came shortly, when the Luftwaffe started to increase the frequency range over which Freya operated, thus tacitly acknowledging that the jamming was becoming effective.

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[31] PRO Avia 7/2303; PRO Avia 7/2404.

Bomber Command contrived to fit two Mandrel jammers in each aircraft in order to cover the 120-130 Mcs band.[32] In addition, No 515 Squadron of Fighter Command continued to patrol some 50 miles off the German occupied coast, with its own Mandrel-equipment. It was then noticed that the loss rate of No 1 Group's Mandrel-equipped aircraft was above average, and it was concluded, correctly, that German night fighters were homing-in on to the Mandrel transmissions with a device known as Freya-Halbe.[33] In an attempt to overcome this disadvantage, Mandrel was adjusted to transmit for two minutes followed by two minutes of silence. By doing this, the chances of an interception were reduced but the effectiveness of the jamming was halved. Moreover, the Luftwaffe then extended the frequency range to 150 Mcs.[34] As each jammer could only operate a barrage over 10 Mcs, either more jammers were going to be required or the intensity of the barrage would suffer. In August 1943, it was calculated by Bomber Command that some 600 aircraft would be required to be fitted with the device, a target then wildly beyond reach. Mandrel, however, was eventually fitted to two-hundred of Bomber Command's aircraft, and consequently the Luftwaffe was then kept busy attempting to keep Freya clear of radio interference.[35]

4. Window, First Use and Consequences

Window was a product of Robert Cockburn's RCM Division of TRE. Mrs Joan Curran of his department undertook much of the development work, but a number of other individuals and

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[32] PRO Air 20/1456; PRO Air 14/1962, p.135.

[33] E.R. Hooton, *Eagle in Flames: The Fall of the Luftwaffe*, p.262.

[34] PRO Air 20/1456.

[35] PRO Air 14/1962, p.135.

authorities were also very much involved. It turned out to be the cheapest and most effective of all the radio countermeasures developed during World War 2. It comprised strips of coarse black paper 27 cms long and 2 cms wide with aluminium foil stuck to one side. If sufficient of these dipoles were released at a certain height, in sufficient quantities, then the Giant Wurzburg radar sets which controlled German night fighter interceptions, as well as the radar controlled anti-aircraft guns and Lichtenstein BC airborne sets, could be completely swamped with false echoes for a time. Thus the release of Window played havoc with the German air defence organisation. The trouble was that it was too effective and could be used by either side. Indeed, the Germans, who had also invented Window or Duppel, did not use it earlier fearing that the RAF would employ it against the Luftwaffe. Consequently, its first operational use by Bomber Command was delayed for more than a year, during which time the most extensive trials were held involving most types of air defence and other radars, used by all three British services.[36] Bomber Command was obdurate, however, and backed by TRE authority to use Window was given at a time when Sir Arthur Harris was planning a series of raids against the city of Hamburg, Europe's largest port and Germany's second largest city.[37] Thus it was first used on the night 24-25 July 1943 when 791 aircraft were deployed, the loss rate amounting to 1.5 per cent of the force. The trend of losses was now definitely in a downward direction, as indeed it had been for a little while. Marking of the target was done with the aid of H2S and by visual means, most of the target indicators falling sufficiently close to the

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[36] PRO Avia 7/2257; PRO Avia 7/2270.

[37] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p. 410.

centre for a concentrated raid to develop quickly.[38] With one blow all German fire control and air reporting systems were rendered useless.[39]

Hamburg was then attacked three more times during the next week or so, the raid on the 27-27 July causing the firestorm.[40] The loss rate, however, increased each time, the figure of 4.1 per cent being sustained on the fourth raid. These attacks on Hamburg shocked the German Command. Something had to be done and, and in desperation, single-engined fighters were ordered to attempt to find the bomber stream, as best they could on their own and then intercept individual RAF aircraft. In addition, or as an alternative, they could head for the target area and try their luck there. Major Hermann and a few others from 2 J Division tried these methods with some success, and it was decided to continue with these methods and develop the technique. The use of single-engined fighter aircraft in this way became known as Wild Boar, which initially became quite successful. Goering ordained that, in future, day and night fighter defence would take priority over all other tasks.[41] Thus it would seem that the offensive use of RCM by the RAF had led to the breakdown of German air defence leading to it being given priority over all German air offence activity. Expediency thus forced the Luftwaffe to introduce the mass control of their aircraft, in an attempt to direct as many of their fighters as possible towards the target area. Here, with the aid of searchlights, Luftwaffe night fighter pilots tried to intercept the attacking

[38] Gebhard Aders, *History of the German Night fighter Force 1917-1945,* p.95.

[39] Cajus Bekker, *The Luftwaffe War Diaries*, p.313.

[40] E.R. Hooton, *Eagle in Flames: The Fall of the Luftwaffe*, p.255.

[41] Gebhard Aders, *History of the German Night fighter Force 1917-1945,* p.101.

bombers. Instructions were passed to them by HF R/T from a central control on 3-6 Mcs, although the old GCI arrangements were left in place to organise interceptions as best they could, through the RAF jamming, along the route taken by the stream. Bomber Command's answer to these changed arrangements was to jam the central control.

Tinsel was already in use against H/F R/T,[42] but now it became imperative to direct jamming with increased power against the critical H/F frequencies. This was achieved with a device known as Special Tinsel. A proportion of all Wireless Operators were thus briefed to operate this new jammer and details of the critical German frequencies in use were passed to the bomber stream by RAF West Kingsdown, through the medium of half-hourly broadcasts. Special Tinsel was instantly effective, but the Luftwaffe soon learned to increase the number of channels employed to pass the running commentaries. To some extent, allocating the different frequencies in use to the various participating Groups offset this tactic. Thus the Luftwaffe was forced to spend time searching for a frequency that was not being jammed.[43] A notable success was achieved on the night of 17-18 August 1943, when the whole of the German defences were deceived into thinking that Berlin was to be attacked, when a small number of Mosquitoes marked the city with target indicators, as if for a major raid. In reality Peenemunde, an important V2 rocket-testing centre, was the target for the night.[44] The British knew little about this target; it had first been brought to their attention

[42] Alfred Price, *Instruments of Darkness*, p.173.

[43] Cajus Bekker, *The Luftwaffe War Diaries*, p.313.

[44] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, pp.422-423.

through the Oslo Report.[45] It was attacked with 596 aircraft, when a Master Bomber was used for the first time. As a result production was set back by at least two months, and reduced the scale of the eventual V2 attacks. It was a moonlit night however and the RAF losses were high, some 6.7 per cent.[46]

5. No 101 Squadron

To add to the jamming potential in the 3-6 Mcs band, No 101 Squadron was equipped with Airborne Cigar (ABC) from early October 1943.[47] With an extra, German-speaking member of crew, its Lancaster aircraft mixed with the main bomber stream and jammed Luftwaffe night fighter communications.[48] These ABC fitted aircraft also carried reduced bomb loads. Because of its special role, the Squadron was often dispatched on raids when its parent formation, No 1 Group, was being rested; this led to the unit taking part in more bombing raids than any other Lancaster Squadron in the Group.[49] ABC was first used operationally on the night 7-8 October, when 343 Lancaster aircraft, from a number of Groups, attacked Stuttgart.[50] The additional, and specially trained German-speaking member of crew, used his three Jostle II transmitters and panoramic receiver, to interfere with German night fighter communications. Only four Lancasters were lost on this raid, representing a figure of 1.2 per cent; but this low rate may have been mainly due to a diversionary raid on Munich by

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[45] BBC Video, Volume One, *The Secret War*, BBC Enterprises Limited, 1994.

[46] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.437.

[47] PRO Air 20/1559; PRO Air 20/1560; PRO Air 20/1561.

[48] PRO Avia 7/2045; PRO Avia 7/2046; PRO Avia 7/2047.

[49] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.437 and p.736.

[50] PRO Avia 7/2045; PRO Avia 7/2046; PRO Avia 7/2047.

Mosquitoes.[51] In the beginning ABC operators received assistance from RAF West Kingsdown, who passed details of active German frequencies. But soon it was realised that good though the RAF Y-Service undoubtedly was, it was limited by the range of German VHF transmissions. Consequently, airborne ABC operators were subsequently authorised to find and jam frequencies independently. The penalty, however, for this RCM protection was in the vicinity of a 1,000 lb. weight reduction in the overall Lancaster bomb load. Nonetheless, No 101 Squadron continued to operate successfully in the bomber stream, providing protection, until the end of hostilities. It was not, however, destined to be placed in No 100 (Bomber Support) Group when this formation was formed later in the year.

6. The Jamming of German Night fighter Communications

As the scale of RAF night attacks against Germany in 1943 and 1944 increased, the Luftwaffe was forced to enlarge its night fighter defences and this gave rise to communication problems. German aircraft, or groups of aircraft, fitted with M/F, H/F, and VHF radios were controlled from the ground, aircrews being given vectors to steer to suitably located beacons, and provided with running commentaries containing information about the course, height, speed and strength of hostile (RAF) aircraft. Subsequently, landing instructions were also passed to their own night fighter crews. No 80 Wing's jamming of German control communications thus increased proportionately. Not surprisingly, No 80 Wing arranged for four additional high-powered ground transmitters to be brought into use.

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[51] Ibid.

At night these HF transmitters could attain ranges of some 300-600 miles and were allocated the code-name Corona.[52] It was first used on the night 22-23 October 1943, when 569 aircraft of Bomber Command successfully attacked Kassel. Unfortunately, the German controller was successful in assessing the target and the loss rate on this rose to the exceptional level of 7.6 per cent, although the general trend of losses in October was downwards.[53] With this device it was now possible to issue false instructions in German to the enemy crews. These emanated from RAF West Kingsdown, but care was taken to restrict the misleading information to landing instructions, frequencies to use and weather conditions at base airfields. Otherwise, it would have been only too easy to disclose more information than was intended. Corona was considered a success as confirmed by Y-Service reports, even when the Luftwaffe suddenly employed a woman's voice and adopted other measures in an attempt to authenticate their own instructions.[54] Eventually, Kingsdown adopted straight jamming with the aid of recordings superimposed on one another.[55] The effects of Corona added to the Luftwaffe's night fighter command and control difficulties, but it also spurred them to greater efforts to find alternative methods of passing instructions to their aircraft. Dartboard was another device introduced and, indeed, one of the first to counteract German M/F broadcast instructions to night fighter crews. Arrangements were thus made in December 1943 for the transmitters at Crowborough in Sussex (Aspidistra) and

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[52] Gebhard Aders, *History of the German Night fighter Force 1917-1945*, p.147.

[53] Martin Middlebrook & Chris Everitt, T*he Bomber Command War Diaries, An Operational Reference Book, 1929-1945*, p.440.

[54] E.R. Hooton, *The Eagle in Flames: The Fall of the Luftwaffe*, pp.258-259.

[55] PRO Air 20/1564.

Huddersfield (Moorside Edge 3) to be available for this purpose during the hours of darkness. Following the precedent set with control of HF frequencies, VHF jamming for this particular purpose was placed in the capable hands of RAF Kingsdown, although over-riding authority remained with HQ No 80 Wing.[56]

Prior requests for jamming action were passed daily by HQ Bomber Command to RAF Kingsdown, with the proviso that the actual hours spent in jamming should be kept to a minimum as the transmitters were normally engaged in propaganda work of the highest importance. At first the transmitters were keyed from Kingsdown but later, in March 1944, Aspidistra radiated its normal Calais or Atlantic propaganda programme. Moorside Edge continued to be keyed from Kingsdown. This placed the Luftwaffe in a dilemma: if it jammed Aspidistra the German night fighter control frequencies would be affected. Alternatively, the Germans could leave Aspidistra alone and accept the propaganda.[57] In December, too, RAF Y stations on the East Coast had indicated that, during recent Bomber Command operations, intercepts on 31.2 Mcs kept referring to a new aid known as Ottakar. Alternating with these R/T instructions on the same frequency were beam type signals with an audio-modulation of 1150 cps. Investigation by aircraft of No 192 Squadron indicated that the beam transmissions originated from Knickebein 3, situated in the Den Helder area of Holland. From this it was deduced that the Knickebein system was now being used to communicate with the night fighter aircraft operating in the defence of Germany, thus further merging

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[56] AM Sigs. Plan (C) Instruction OMS 79 dd. 27 January 1943, quoted in PRO Air 41/46, pp.107-108.

[57] Ibid., dd.16 March 1944.

offensive with defensive systems.[58]

This was indeed a new departure and one that No 80 Wing had to address as quickly as possible. To overcome Ottakar, No 80 Wing used a high power transmitter sited at Mundesley, which employed a jostle-type modulation, using this new countermeasure under the code name Rayon. A measure of success was obtained with this equipment, in spite of the long ranges involved. By comparison, opportunities to impose countermeasures in the HF bands were limited, compared with the Luftwaffe's use of VHF. They were confined to actions taken against German W/T broadcast radar plots and against W/T HF instructions, the German W/T broadcasts being described under the code word Oculist. This came about when intercepts indicated that the German Air Force had resorted to broadcasting radar plots in the 3-6 Mcs band, when its landline system had reached saturation point. This jamming of Oculist traffic was given the codename Purple and was to be implemented by the British Army with No 16 sets. However, in view of the usefulness of Oculist traffic as a source of intelligence, Purple was reserved for the Invasion and then only after Moonshine and Mandrel had been used first. In the event the transmitters were never used in this role. Later on and during the final stages of the war, the transmitters earmarked for Purple, which were now positioned at Hope Point, Sussex, were employed as a countermeasure against German W/T night fighter control in the HF band. The operation was supplementary to Drumstick, as HF Fidget, and involved the jamming of HF W/T by high-powered transmitters under the control of RAF Cheadle.[59]

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[58] PRO Air 41/46, pp.101-102.

[59] No 100 Gp. File MS/407/2/INT dd. 29 February 1944, quoted in PRO Air 41/46, p.101.

7. The Rise in German Fighter Strength

As Bomber Command began its major assault on Berlin in November 1943 the loss rate started to rise to unacceptable levels, in spite of all the air and ground countermeasures being taken. Harris was forced to withdraw his Stirling force on account of their poor altitude performance, and the Mark 2 and 5 versions of the Halifax were soon to join them for similar reasons.[60] The German air defences were again in the ascendant. All the time British intelligence had been warning of a continued increase in the front-line strength of fighters based in Germany. No Luftwaffe fighter aircraft losses were replaced in the East, or in the Mediterranean area, priority clearly being allocated to the Home front.[61] In the United Kingdom, Naval Intelligence commented that unless the German fighter strength was checked, bombing of Germany would become impossible.[62] Indeed in August 1943, at the Quebec Conference, it had been disclosed that while the overall Luftwaffe fighter strength had increased by 22 per cent since the previous January, in Western Europe it had doubled.[63] Erhard Milch had done his work well and obtained priority for fighter production. The Deputy Chief of Air Staff then asked, without avail, for Bomber Command to heed the Pointblank Directive and attack Germany's factories producing fighter aircraft.[64] Even the mighty 8th United States Army Air Force seemed powerless to prevent the massive increase in German fighter strength. On 17 August 1943, three-

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[60] Martin Middlebrook & Chris Everitt, *The Bomber Command War Diaries*, p.446.

[61] F.H. Hinsley, *British Intelligence in the Second World War*, Vol.3, Part 1, p.294.

[62] Ibid.

[63] Ibid.

[64] Combined Bomber offensive to destroy the German Air Force, approved at the Washington Summit, May 1943. Max Hastings, *Bomber Command*, p.187.

hundred-and-sixty-three B17s had set out to attack the ball-bearing factory at Schweinfurt and the Messerschmitt works at Regensburg. Sixty of the B17s failed to return. These heavy losses coupled with bad weather then restricted US Army Air operations over Europe in September. October saw a return to operations over Germany and on the 14th of the month two hundred and ninety one B17s returned to finish off ball-bearing production at Schweinfurt. The results were similarly unacceptable, sixty aircraft lost and many more damaged. Deep raids inside Germany by the Americans had thus become prohibitive, because of losses, and had to be abandoned until long-range fighter escorts became available in the New Year, 1944.[65] As Sir Arthur Harris took on Berlin, hoping that by doing so he could shorten the war and obviate the need for a large assault landing on the German occupied French coast. He called for the Americans to join in and help him, but this they were clearly unable to do.

8. The Hard Road to Berlin

Bomber Command had first bombed Berlin as early as 25 August 1940 when, with cabinet approval, a mixed force of 80 Hampden and Wellington aircraft carried out an attack against military objectives, but not very successfully. Thick cloud covered the target and the Hampdens were at the limit of their fuel capacity, the only bombs falling within the city limits destroyed a wooden summer–house and slightly injured two individuals.[66] The city was of course, not only the capital of Germany but an important centre of production as well. It produced aircraft, aircraft engines, ball-bearings, and radar. As Harris started his major

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[65] Jeffrey Ethell and Alfred Price, *Target Berlin*, p.5.

[66] PRO Air 41/57, p.447.

campaign against Berlin, thick cloud prevented an assessment of the results. It was to be attacked fifteen more times during the next four-and-half months. This period was marked by a Luftwaffe reorganisation of night fighters, which led to rising RAF loss rates.[67] The Wild Boar system, which came into being after the RAF first introduced Window, was overtaken by the success of the Tame Boar twin-engined night fighters, which were being fitted with latest AI, SN2, and provided with every assistance to find the bomber stream on its way to and from the target. By the summer of 1943 about 80 per cent of the German force had been equipped with it.[68] Moreover, apart from some intelligence reports, the RAF was unaware of its existence; certainly insufficient evidence was available in 1943, to produce an airborne device to counteract it. It thus remained unjammed for at least six months.[69] The German capital was a hard slog, a distant target, and some thirteen degrees east of Greenwich, with weather that was often marginal. Moreover, navigation was difficult even though the Pathfinders of No 8 Group were equipped with the latest version of H2S, the Mark 3. Whatever the weather and cloud conditions, the landmass was always clearly portrayed in white, and water in black; but even so, the Plan Position Indicator definition of Berlin was invariably poor, because of the number of lakes in the area.[70]

Main force was using Monica, a tail warning device, and was also being equipped with H2S, and the increase in transmissions stemming from hundreds of aircraft, using IFF as well,

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[67] Gebhard Aders, *History of the German Night fighter Force 1917-1945*, pp.110-111.

[68] E.R. Hooton, *Eagle in Flame:The Fall of the Luftwaffe*, p.252.

[69] PRO Air 20/1962, p.140.

[70] Alan W. Cooper, *Bombers over Berlin* (Patrick Stephens Limited, 1989), p.19.

undoubtedly helped the Luftwaffe to track the bomber stream and thus direct German night fighters into it.[71] Nevertheless, considerable damage was done to the city and more extensively than was disclosed at the time. Berlin, on occasions, was thus hit hard; but it was never wrecked from end to end as Air Marshal Sir Arthur Harris had hoped and, consequently, his desire to end the war quickly without the need for a major amphibious landing, and with as few casualties as possible, was never achieved.[72]

9. To Confound and to Destroy

Since 1942, Mandrel had helped to jam the German early warning Freya radars and the later versions were now being used by the US 8th Army Air Force, as well as the RAF. The Germans thus reacted to all this pressure and from the spring of 1943, they extended the frequency range of the Freyas until it was out of reach of Mandrel.[73] German ground stations began broadcasting a running commentary on the progress of the RAF bomber force on R/T employing Freya and Benito.[74] It was essential to the German defence that every night fighter was equipped with radar, thus making it easier to find and intercept the bomber stream by making full use of the emissions emanating from individual RAF aircraft using ABC, Mandrel, IFF, H2S, Monica and Oboe.[75] These emissions were all plotted by a route-tracking service, which progressively became very efficient indeed. Moreover, the AI Lichtenstein was giving way to SN2, which because of its wide field

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[71] PRO Air 20/1962, pp.79-82; Gebhard Aders, *History of the German Night fighter Force, 1917-1945*, p.152.

[72] Henry Probert, *Bomber Harris: His Life and Times* (Greenhill Books, 2001), p.249.

[73] E.R. Hooton, *Eagle in Flames: The Fall of the Luftwaffe*, p.254.

[74] PRO Air 20/1668.

[75] Ibid.

of view was well suited for use against the highflying bomber stream. Moreover, it remained unaffected by the current type of Window employed.[76] As a consequence, the employment of IFF over the Continent was stopped; unwisely the order did not become fully effective until February 1945.

Britain's first use of airborne countermeasures thus was not very successful, and as the effective German radar-controlled defences began to inflict more and more casualties on the RAF, inevitably the loss rate moved upwards again. Various countermeasures such as airborne Mandrel and Moonshine had been introduced and employed by Fighter Command. No 80 Wing was conducting ground jamming and now Bomber Command was building up its own inventory of devices with Tinsel, Mandrel and Window. Little thought, however, had been given to co-ordinating their use and, sooner or later this state of affairs would have led to a number of serious technical and tactical problems. Moreover, in the latter half of 1943, TRE began to be inundated with a plethora of demands for unrelated radar aids and, as this Establishment had invariably attempted to design equipment closely related to its tactical use, clarification of the scientific effort required became essential, if the limited resources available were to be properly employed. Moreover, dispersal of the countermeasure effort was uneconomic and had to be brought under control. In the summer of 1943, TRE had given some thought to the matter and on 13 September, 1943 submitted proposals to the Controller of Communications, Sir Robert Renwick.[77] The latter in turn wrote to

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[76] PRO Air 20/8953, p.67.

[77] PRO Avia 7/2303, Minutes of a Conference held on Wednesday, 29 September 1943, at Air Ministry, Whitehall, to discuss proposals for the formation of a Combined Radio Countermeasure Organisation for the support of the Air Offensive.

the Air Ministry suggesting that Fighter Command's Night Intruder and Serrate equipped Squadrons should be transferred to Bomber Command and form part of a new bomber support Group, to be formed especially for the purpose.

Such was the urgency with which this problem was addressed that no less a person than the Vice-Chief of Air Staff, Sir Norman Bottomley chaired a Most Secret and significant meeting at the Air Ministry on 29 September 1943. R.H.M.S. Saundby, standing in for Sir Arthur Harris, made out a good case for a separate RCM Organisation and for Fighter Command's Night Intruder and Serrate equipped Squadrons to be placed under one formation as well. Understandably, the AOC-in-C Fighter Command, Air Marshal Sir Trafford Leigh-Mallory, was not keen on transferring his squadrons to another Command. The Chief Superintendent of TRE, Mr A.P. Rowe, who believed that the new Group should come under Fighter Command, supported him. After further discussion, however, Sir Trafford agreed to the transfer of the Serrate equipped units. The meeting then decided that a recommendation to form a new Group in Bomber Command charged with the sole responsibility of co-ordinating and applying all radio countermeasures including the collecting of relevant information and studying appropriate tactics, should be forwarded to the Chief of Air Staff.[78] So far as aircraft were concerned, the meeting agreed that high-flying aircraft, capable of producing additional electrical power, were necessary and General Ira C. Eaker, Commanding General 8th Air Force, pointing out that the 8th Air Force would also benefit from this new arrangement, agreed to approach the US Authorities to obtain the necessary B17 aircraft. It was also

[78] PRO Avia 7/2303.

proposed that the new formation should be named, No 100 Group, and should control: No 80 Wing, with all its manifold transmitters and one hundred plus Watcher Sites; Nos 141, 169 and 239 Serrate Squadrons from Fighter Command, Serrate being a device which homed on to the radar emissions from a German night fighter; No 515 Mandrel and Moonshine Squadron; No 1473 Flight; No 192 Squadron from HQ No 3 Group; an airborne Mandrel Screen to replace most of the individual sets carried by Main Force aircraft; a Moonshine Squadron and, although this did not materialise, No 515 Squadron did join No 100 Group; No 214 Squadron with Fortress aircraft in order to provide a Jostle IV platform and eventually to provide part of a Special Window Force and a Special airborne investigative Squadron, No 101.[79] This last named unit, however, was never destined to become part of No 100 Group.

10. No 100 Group Becomes Operational

Sir Arthur Harris naturally wanted his new Group to become operational as quickly as possible and, consequently, Air Commodore Addison decided in the first instance to form No 100 Group at RAF Radlett, at this time in No 26 (Signals) Group. The formal date of inception was 1 December 1943, and on 3 December 1943, the Group moved to RAF West Raynham, in Norfolk, the station itself being transferred the same day from No 3 Group to No 100 Group.[80] Of greater importance and in accordance with the decisions taken by the Conference on 29 September 1943, one of the original Serrate Squadrons of Fighter Command, No 141 equipped with Beaufighters, later Mosquitoes, arrived from

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[79] Ibid.

[80] PRO Air 20/1962, but see PRO Air 25/777 for earlier date 23 November 1943.

Wittering to become the first of several such units that were to play an important part in the Group's bomber support activities. Further additions to the new formation followed over the next few days and these included: RAF Station Foulsham on 7 December 1943 with No 192 Squadron, the specialist RCM unit formed from No 1474 Flight; RAF Little Snoring on 7 December 1943 and No 169 Mosquito night fighter Squadron from Ayr, No 13 Group; RAF North Creake and Swannington also on the 7th of the month. Further additions from No 13 Group arrived on the 9th and 10th in the shape of No 239 Mosquito night fighter Squadron to West Raynham and No 1692 Special Duties (SD) Flight to Little Snoring respectively.[81] Meanwhile, the whole of No 80 Wing, RAF Radlett and the entire Wing's numerous outstations had been transferred to Addison on 11 November 1943.[82] On 12 December 1943, No 1473 Flight was moved to RAF Foulsham in order to concentrate the electronic intelligence (ELINT) units on one base. Three days later, in accordance with the decisions taken on the 29 September 1943, No 515 Squadron, the first unit to have had Moonshine installed, was transferred from RAF Hunsdon, in No 11 Group to Little Snoring, in Norfolk; its aircraft were in poor condition, the unit having been non-operational since the previous July, having had no role in Fighter Command. Some time therefore was to elapse before this Squadron would be capable of Serrate operations in No 100 Group.[83] But what Bomber Command was really waiting for occurred on 30 November 1943, when No 192 Squadron completed No 100 Group's first radio countermeasure (RCM) operation in support of Bomber Command.

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[81] Martin Streetly, *Confound and Destroy*, p.35.

[82] Ibid., p.25.

[83] Ibid., pp.19 and 36.

This was followed by No 141 Squadron which was at first equipped with Beaufighters and then Mosquitoes, which completed the first 100 Group Serrate operation on the night 16-17 December 1943, in support of a major raid on Berlin. It was disappointing for Bomber Command to have to record that in spite of the two Beaufighters and two Mosquitoes of No 100 Group involved, together with the support provided by No 80 Wing and No 101 Squadron, 5.2 per cent of the main force of Lancasters was lost on this occasion. The German controllers managed to plot the course of the bomber stream with great accuracy, and many interceptions took place at the coast of Holland.[84] No 141 Squadron, however, did claim that a Bf 110 was damaged west of Berlin, after an indecisive engagement. The entire effort for the night of 589 sorties produced a total casualty rate of 9.3 per cent.[85] No 192 Squadron was also active during the month investigating German radio transmissions from the Baltic area to the Bay of Biscay, and along main force routes. No 473 Flight also contributed to the Group's activities during December, by operating on fifteen nights, intercepting those German VHF transmissions, which could be received over the United Kingdom. Overcoming a myriad of difficulties, Addison's new and unique Group was flying on operations in support of its parent Command before the end of 1943. In due course it was to provide many a surprise for the Germans.[86] By the beginning of 1944 it was already very much part and parcel of Bomber Command's Order of Battle, even though it would be some time before it would become fully effective.

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[84] Martin Middlebrook & Chris Everitt, *The Bomber Command War Diaries, An Operational Reference Book, 1939-1945*, p. 458.

[85] Ibid. pp.459-460.

[86] Adolf Galland, *The First and the Last*, p.237.

While the heavy jamming Squadron of B17s was being modified for night flying and fitted out with TRE designed jamming equipment at RAF Sculthorpe and Prestwick,[87] other (fighter) units of the Group were being fitted with Serrate and rearward looking AI Radar. Of necessity, the fighter re-equipment programme had been given considerable priority, impetus being given to the programme by the presence of Addison's Senior Air Staff Officer (SASO), Air Commodore Roderick Chisholm. This officer had been specially selected for the appointment, in view of his knowledge and experience of night fighter tactics. He had come from the Fighter Interception Unit at RAF Ford, in Sussex.[88]

Summary

In 1942 Bomber Command was faced with the dilemma that if it did not improve its navigation and bombing it could be disbanded or greatly reduced in size. However, if it did adopt some of the new British radio aids now being developed by TRE in order to correct the deficiencies, it was likely that the position of the bomber stream would be disclosed to the Germans, leading to even larger losses. So powerful were the critics, that indirectly, the results of the Butt Report, together with the subsequent actions taken, saved Bomber Command. From now on the Air Ministry and, indeed the Command itself, would welcome all the electronic aids it could obtain in spite of the disadvantages. Gee had been invented and was in production, but there was some disappointment about its accuracy when used as a bombing aid. It did prove, however, to be a great advance over the previous and

[87] Martin Streetly, *Confound and Destroy*, pp.38-39.

[88] Roderick Chisholm, *Cover of Darkness* (Chatto and Windus, 1953), p.116 and p.157. Air Commodore Chisholm was Senior Air Staff Officer, HQ No 100 Group.

older methods of navigation. The arrival of Sir Arthur Harris on the scene also seemed to put new heart into Bomber Command. He started off by carefully selecting the location of targets to be attacked, thus improving the chances of success. By reducing the bomber stream by time and space, he also helped to bring down the number of casualties, if only temporarily. But what really caught the public imagination, and this was an important factor to consider, was the advent of the first ever one thousand bomber raids. He thus secured a niche for Bomber Command to continue to prosecute the war.

As one would expect, the Luftwaffe reacted to these aggressive tactics and General Kammhuber devised a defence system of searchlights, guns and night fighters which, combined with radar, proved to be a formidable obstacle for Bomber Command to overcome. Indeed, losses began to mount, sometimes reaching a rate of 5 per cent and higher. Certainly, by January 1942 the trend of losses had started to climb, but it took until August, some six to seven months later, before the Operational Research Section at High Wycombe, published a paper on the advantages of airborne radio countermeasures. Even then, the authority of the Air Ministry had to be sought before the devices could actually be used. Obviously, there was still reluctance in some quarters to start using airborne jammers. Meanwhile, Shiver had been introduced and the Pathfinder Force created, but not without controversy and TRE was busy developing Oboe and H2S. At long last, in October 1942, a conference was held to decide how best Bomber Command could use the range of radio countermeasures available to them. By now, with aid of Mandrel and Tinsel, losses began to fall and Sir Arthur Harris turned his eyes on Berlin. Oboe, in spite of its limited range, proved to be a very accurate bombing device in March 1943, during an attack on Essen, when 3.2% of the attacking force was lost. But now the improved German defences started to gain the upper hand and the trend of losses started to rise. It was thus decided to equip some two hundred bombers each with two Mandrels, but there were problems with this arrangement, especially when it was discovered that the Germans were tracking Mandrel emissions with a device called Freya-Halbe. Ground Cigar operated by No 80 Wing was used to interrupt German R/T control of their night fighters but, unfortunately, although powerful, it was limited by range.

Window was undoubtedly a long time in gestation and was probably the most tested of all the RCM devices before being used. It certainly was the cheapest and most effective. It was first deployed over Hamburg in July 1943, with great success. It rendered the existing German air defence organisation unworkable and forced the Germans to develop other methods. One of these was Wild Boar, which some Luftwaffe pilots welcomed, as it freed them from the close control conditions previously in use. As the German Air Force became proficient in these new methods of air defence, the loss rate began to rise again until Corona and ABC were introduced in September and October. All the time the numbers of German fighter aircraft were increasing and the US 8th Air Force felt the full onslaught of the strengthened defences during an attack carried out against the ball-bearing plant at Schweinfurt in October. Henceforth, deep penetration raids, by day, had to be abandoned until effective fighter escorts could be provided. It was at this juncture that the C-in-C of Bomber Command decided to attack Berlin in strength. As the concentrated series of RAF attacks on Berlin started, in November 1943, the Luftwaffe was developing an even more effective system of defence, the Tame Boar. This involved twin-engined fighters being fitted with the latest AI, SN2 Naxos, which was used to home on to RAF H2S transmissions, and Flensburg, used for homing in on to the RAF Monica transmissions. So strong had the German night defences become, that some 250 Stirlings and Halifaxes had to be withdrawn almost immediately from the Order of Battle, thus reducing the bombing force by about one fifth of its effective strength. Moreover, even with the latest H2S sets, the Pathfinder Force had difficulty interpreting the landmass because of the numerous lakes in the area. Nevertheless, Berlin was hit and often hit hard; but the Command was simply not strong enough to destroy the city, which was one of the aims Sir Arthur Harris had hoped to achieve in order to shorten the war.

Towards the end of 1943 a number of different air and ground formations, Fighter Command among them, were employing radio countermeasures and thus there was danger of creating a number of tactical and technical difficulties. Clearly, then, there was a need for a single controlling authority. Thus in September 1943, it was decided to create No 100 (Bomber Support) Group to discharge these responsibilities and to control those elements of Fighter Command which were providing support to Bomber Command on the Continent. Command of this new and unique formation, which was to have its own fighter squadrons for Serrate patrols and Intruder purposes and squadrons of heavier RAF and US aircraft, was entrusted to Air Commodore, later Air Vice Marshal, Addison. It was noteworthy that the highly secret conference, which recommended its creation, was attended by representatives of a foreign, albeit, allied power. There may have been delay in setting up the new Group, there were after all a myriad of administrative problems to overcome, but once it was formed the AOC wasted little time. From the beginning of December, flying units and RAF stations came flooding in. Fighter Squadrons came from Fighter Command and Bomber units from other Bomber Groups. Before the year was out, No 192 Squadron had successfully completed the Group's first RCM mission with four Wellington aircraft and No 141 Squadron, with two Beaufighters and two Mosquitoes, inaugurated

Bomber Command's Serrate patrols, operating near the routes used by main force bomber aircraft on a raid to Berlin. The main burden of support in 1943 thus fell on the three Serrate Squadrons, 141, 169 and 239, which were all facing re-equipping with Mosquito 11 aircraft.

Having discovered how and why No 100 Group was formed, it will now be logical to continue with RAF Bomber Command up until the point when control was transferred to the Supreme Allied Commander, General Eisenhower, prior to Operations Neptune and Overlord. The following Chapter investigates Bomber Command’s preparations for D-Day and includes the United States Army Air Force assault on the German aircraft industry during Operation Big Week.

CHAPTER EIGHT: 1944: TOWARDS D-DAY AND BEYOND

1. Berlin 1944

The New Year opened with two attacks on Berlin, as Sir Arthur Harris continued with his air assault on the German capital. The bombing was either inaccurate or scattered; neither could be considered satisfactory from the British point of view. Losses on these two occasions for Bomber Command were 6.7 per cent and 7 per cent respectively of the forces involved, even though on the latter raid support was provided by two Beaufighters of No 141 Squadron, of No 100 group, which carried out Serrate patrols. The first major raid against Brunswick occurred on the night 14-15 January 1944; 7.6 per cent of the force was lost. German radar detected the bomber stream of four-hundred-and-ninety-six Lancasters and two Halifaxes, some forty miles off the English coast. The Luftwaffe controller then proceeded to give an accurate running commentary by radio of the progress of the force to the waiting German night fighters. This enabled interceptions to be made from Bremen (nine degrees east) onwards towards the target and as far as the Dutch coastline on the return leg. The target was smaller than usual and the Pathfinder Force target marking indicators inaccurate. Most of the bombs fell in the south of the city, the countryside, and on small towns such as Wolfenbuttel. On the same night, however, the German Controller ignored the presence of some eighty-two aircraft attacking flying-bomb sites at Ailly, Bonneton and Bristillerie in France, together with eleven Mosquito sorties to Magdeburg and six to Berlin, nine Radio Countermeasure sorties, two Serrate patrols, twenty minelaying aircraft on Gardening (minelaying) duties off Brest and the Frisians and thirty six Operational Training Unit sorties, all of which were conducted without loss to the RAF.

Six days later, Bomber Command returned to Berlin again, this time with a mixed force of some seven hundred and sixty nine aircraft. No 100 Group was now operational and provided a number of diversionary activities on this occasion, consisting of five Serrate patrols and six RCM sorties. But these were not enough to prevent the loss of 4.6 per cent of the force. Sir Arthur Harris continued with his assault on Berlin right up to the end of January, with only two raids after that date. Bomber support operations, along with a number of ingenious diversions, were used throughout this period in an attempt to reduce the casualties sustained by main force. These distractions, however, were not always successful; intelligence about German defence tactics was not as good as it should have been and thus main force casualty rates at this time seldom fell below 5 – 6 per cent, and sometimes went higher. In February 1944, on the night of the 8th, No 5 Group, with twelve Lancasters using a new technique, the marking of targets at very low level, attacked the French Gnome and Rhone aircraft engine factory at Limoges. The factory, virtually undefended, was severely damaged and no Lancasters were lost. Wing Commander Leonard Cheshire led the raid, which was a compete success. It proved Bomber Command could find, and bomb successfully, a small target by night; albeit an undefended one. A week later the penultimate RAF raid against Berlin took place, with the largest force ever used against the capital – eight-hundred-and-ninety-one mixed Lancasters, Halifaxes, and Mosquitoes. The German controllers were able to plot the bomber stream soon after it left the United Kingdom. Damage was extensive, and some important war industries were hit; but some of the bombing was scattered.

Only 1.5 per cent of the force was lost during a raid on Stuttgart on 20 February, but this low figure may have been due to a large preliminary feint across the North Sea, a successful diversionary raid on Munich and seven Serrate patrols mounted by No 100 Group. During the remainder of the month other raids took place against Schweinfurt, Augsburg and Stuttgart. The low casualty rate of 0.7 per cent against the last named target was mainly due to thick cloud; but extensive diversionary tactics helped together with ten No 100 Group Serrate patrols. Thanks to the activities of No 192 Squadron's systematic survey of the Germans radar chain, combined with other intelligence from sources such as Enigma and the Y-Service, the Serrate patrols and diversionary tactics started to improve and maintain the downward trend of Bomber Command losses.

Two distinctly different raids marked the month of March. The Command continued to attack German towns and cities as hitherto, but on the night 6-7 March, the first of a series of raids on railway targets occurred, prior to the invasion of Europe. This was something of a test case to see if Bomber Command could consistently find and hit small targets by night. Trappes was an important French rail centre situated to the south west of Paris.[1] Enormous damage was done to railway tracks, rolling stock and installations, and because the main stream did not have to penetrate very far to the east, no British aircraft were lost.

The second attack took place against Nuremberg on the night 30-31 March 1944. This raid was a disaster, mainly due to the clear weather over the target when an early forecast had predicted high protective cloud, the rising of the moon during the actual attack, and poor routing; some of the main force aircraft flew over the radio beacons where the German fighters were actually

[1] PRO Air 14/1962, pp.23-24.

assembling.[2] Some ninety-five Lancasters and Halifaxes were lost out of a total of seven-hundred-and-ninety-five aircraft, representing a loss rate of 11.9 per cent, the biggest loss of the war.[3] The Luftwaffe claimed one-hundred-and-thirty-two bombers shot down.[4] Again the diversions and support operations were extensive, and on this occasion No 100 Group contributed five RCM sorties and nineteen Serrate patrols; but all to no avail.

During the month of March, however, Bomber Support provided a total of ninety-five Serrate patrols resulting in the destruction of five German aircraft. No 192 Squadron continued its investigation of the Luftwaffe radar chain, whilst No 214 Squadron carried on with its conversion. All of this was helpful, but not effective enough to make a real impact on bomber operations. Nevertheless, the Group was regularly participating in operations and rapidly learning how to provide an efficient and effective radio support to its parent command. By 31 March 1944, the main battle for Berlin was over for Bomber Command, although it was attacked by the US 8th Air Force by day, from the 6 March 1944, until 1 April 1944, when the Combined Bomber Offensive ended.[5] Since 18 November 1943, Bomber Command had launched sixteen heavy attacks on the capital and, in spite of the radio countermeasures which could be provided at the time, these had cost the RAF 1,047 aircraft, with seven thousand crews lost and 1,682 aircraft damaged, out of a total of 20,224 sorties. At the end of it all, Bomber Command was nearly destroyed and simply could not

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[2] Martin W. Bowman and Tom Cushing, *Confounding the Reich; The Operational History of 100 Group (Bomber Support) RAF*, p. 44.

[3] E.R. Hooton, *Eagle in Flames: The Fall of the Luftwaffe*, p.261.

[4] Adolf Galland, *The First and the Last*, p.237.

[5] Jeffrey Ethel and Alfred Price, *Target Berlin* (Book Club Associates, 1981), p.31.

sustain such casualties and continue the bombing of Germany. Bomber Command and 8th US Army Air Force were now about to come under the Supreme Allied Commander, General Eisenhower, and be directed to attack targets, many of them small, in direct support of the forthcoming invasion.

2. Big Week

Just as the Bomber Command assault on Berlin was ending, the fierce resistance shown by the German fighters by day, as well as by night, determined the allies to implement the plan to attack the German aircraft industry, in particular those factories producing fighter aircraft. The United States Army Air Force also initiated a war of attrition against the German fighter force, which prepared the way for success at Normandy.[6] Accordingly, on the night 19-20 February 1944, Bomber Command attacked Leipzig in order to weaken the defences prior to the US Army Air Force's operations the next day. A large number of diversions were mounted on this occasion which included: mine-laying in Kiel Bay, Oboe-assisted bombing of night fighter airfields in Holland, fifteen Mosquitoes bombing Berlin and twelve 100 Group Serrate patrols. The raid was an unhappy one for Bomber Command as the German Controller was only partly deceived by the mine-laying, enabling him to direct attacks against the bomber stream all the way to the target. Some 9.5 per cent of the force was lost. Early the following morning, about one thousand heavy US bombers escorted by fighters, many of them the new long-range P51B Mustangs, with the Rolls Royce engine, from seventeen American Groups and sixteen RAF Fighter Squadrons, took off to attack twelve aircraft

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[6] Air Vice Marshal R.A. Mason, *Air Power: An Overview of Roles*, p.59

factories in the Leipzig and Posen areas. These were extensively damaged for the loss of twenty-one bombers. [7]

During the next five days more then 8,300 tonnes of bombs were dropped by the USAAF in daylight, severe disruption being caused to the German aircraft industry.[8] The overall American loss for 3,800 heavy bomber sorties being two hundred and twenty six aircraft, an acceptable loss rate of 6 per cent.[9] Big Week did not kill off the Luftwaffe, thanks to feverish activity by the repair organisation; but by the end of February, the Luftwaffe had lost 17.9% of its pilot strength, with 225 pilots killed, and 141 wounded.[10] These were punishing figures; daylight air superiority was irrevocably passing to the allies.[11] Nevertheless, the German Air Force was still capable of inflicting heavy casualties on the allied air forces by day and night. Radio countermeasures were still very much in demand.

3. RCM: Action and Reaction

It now became more important than ever to monitor the effectiveness of RAF countermeasures, air and ground, and to note especially the changes in German procedures and frequencies, one of the tasks specifically allocated to the now more effective formation, No 100 Group. The Y (listening) Service remained one of the essential lynchpins in this process and normally the first to discern the need for any counteraction. By early 1944 the original

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[7] Donald L. Caldwell, *JG 26* (Orion Books, New York, 1991), p.220.

[8] Stephen E. Ambrose, *The Wild Blue* (Simon and Schuster, New York, 2001), p.118.

[9] Jeffrey Ethel and Alfred Price, *Target Berlin*, p.8.

[10] Donald Caldwell, *JG 26*, p.226.

[11] Richard Overy, *Why The Allies Won*, p.124.

Freya frequencies of 120-130 Mcs had been enlarged through 150 Mcs to 70-200 Mcs, thus making Mandrel less effective, until modified. Moreover, the RAF bomber stream continued to be tracked through IFF and other transmissions; and although these emissions were restricted, they continued to be used.[12] The German use of HF W/T to provide running commentaries for air defence purposes; these were more difficult to jam, but RAF Cheadle passed appropriate details to No 80 Wing who used Drumstick in the 3-6 Mhz band, from the night 21/22 January 1944 during an attack on Magdeburg.[13] The marking was not concentrated on this occasion and most of the bombs fell outside the city.[14] Although the number of German frequencies in use exceeded the available RAF transmitters, the jamming at least caused the Luftwaffe considerable inconvenience.[15] The Germans used VHF R/T on 31.2 Mcs and three ABC transmitters were modified to jam this frequency purposes and, though not ideal, little more were heard of these particular transmissions after jamming started.

The Germans then started to use M/F navigation beacons for passing instructions to fighter aircraft. When No 80 Wing became aware of this practice Fidget, first known as M/F Corona, was successfully employed by them from April 1944. It involved the utilization of certain modified Meacon transmitters radiating random automatic Morse code signals on the exact frequency of the German Benito beacons in order to interfere with the control of

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[12] PRO Air 14/1962; PRO Air 14/2347; PRO Avia 7/210.

[13] Gebhard Aders, *History of the German Night fighter Force 1917-1945*, p.152; PRO Air 41/46, p.104.

[14] Martin Middebrook and Chris Everitt, *The Bomber Command War Diaries*, p. 466.

[15] Martin Streetly, *Confound and Destroy*, p.45.

Luftwaffe fighter aircraft, which used the reception of an audio tone by each aircraft and its subsequent retransmission.[16] Airborne action was also taken with ABC jammers, together with a suitable modulator designed to radiate an audio note similar to that of the Benito tone. The gradual reduction in the use of Lichtenstein AI on 490 Mcs, made Serrate less effective. Ground Grocer was employed against this AI, but its range was such that it could only cover a small area of Holland and Belgium. Serrate had first been used by Fighter Command in support of Bomber operations in June 1943, the squadrons later being incorporated into No 100 Group. The equipment had then been fitted into the night fighters of No 100 Group.

Early in 1944 it had become noticeable that fewer Serrate contacts were being obtained and, at the same time there was less activity in the 490 Mcs band. It was thus deduced that FuG 202 Lichtenstein B/C was being replaced, as indeed it was with FuG Lichtenstein SN2.[17] In spite of the best efforts on the part of the Y-Service and No 192 Squadron, however, little information was known about the new German device. The only clues being a few radar signals around 160 Mcs which might have emanated from it, and a photograph taken by a fighter camera gun of a novel type of aerial array which could have been used for AI purposes. 167 Mcs was the frequency of a German tail-warning device, Naxos, which could possibly have been modified, for AI use. On the assumption that 160 Mcs was the right frequency, a quantity of Window, Type Y, was produced in readiness. 160 Mcs proved to be incorrect, however, and the special Window was never actually used on

[16] PRO Air 41/46, p.109.

[17] Gebhard Aders, *History of the German Night fighter Force 1917-1945,* p.123.

operations. This was because on 12-13 July 1944, luck and No 80 Wing's Meacons intervened to bring about an accidental landing in the United Kingdom of a Ju88, undamaged and with SN2 fitted and in working order, solved this particular problem.[18] Examination of the equipment of the Ju88, by RAE Farnborough, showed that the SN2 worked on a frequency around 90 Mcs and, fortunately, a remedy was immediately available. Type MB Window had been devised for use against German early warning radar in connection with the D-Day landings, and was designed to cover all frequencies between 70 and 200 Mcs.

Good stocks were still in hand and, on 23-24 July 1944, it was used on a bombing operation against Kiel; the first raid by Bomber Command on a German city for two months. It was also the first time that an airborne Mandrel Screen had been used with aircraft provided exclusively by No 100 Group, although orbiting Mandrel centres had been used during the Overlord air operations. During 1944 individual Mandrel sets had been withdrawn from main force aircraft and used instead as part of a jamming screen against the German early warning system. By the end of 1944 the Mandrel screen incorporated radar equipments of greatly improved design; operating on frequencies of 40 Mcs to 180 Mcs.[19] The Mandrel Screen helped to confuse the German Controller and was able to prevent any accurate assessment of the incoming bomber stream until it was within twenty miles of the occupied coastline.[20] Two nights later in a raid against Stuttgart, when the Mandrel screen was in use, together with Window, RAF Y-Service intercepts indicated that the German night fighter controller had successfully

[18] Ibid., p.177.

[19] PRO Air 20/8953, p.63.

[20] Ibid.

followed the movement of the RAF bomber stream and organised an efficient defence, yet losses, worked out after the raid from station returns, were again surprisingly low.

From trials conducted after the war it became clear that this was largely, if not entirely due to Window, Type MB, interfering with German AI. From that time onwards, one or other of the W types of Window was used, later in conjunction with the airborne electrical jammer, Carpet.[21] Window was also a successful countermeasure against Wurzburg, but only, of course, when the aircraft discharging it, at the recommended rate, was present. Window was of little value to aircraft outside the main bomber stream and the Window screen and provided little or no protection to those aircraft in the lead, which, invariably, were Pathfinder aircraft. Carpet thus filled the gap. The device had been designed by TRE to jam Wurzburg electrically and comprised an automatic search receiver and jammer operating in the 530-580 Mcs band. As a Wurzburg signal was received, jamming started for two minutes, after which time the receiver continued to search for other signals. The RAF Pathfinders of No 8 Group were given priority and were the first RAF recipients of this equipment; installation starting in March 1944.[22] The US Army Air Force in Europe used the device extensively; and because of this the Luftwaffe reacted vigorously by enlarging the Wurzburg frequency bands. Nevertheless, the first results were satisfactory and the loss rate of aircraft equipped with this device proved to be lower than average: damage from Flak was

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[21] PRO Avia 7/2401, Airborne Carpet; PRO Avia 7/2402, self-tuning Jammer; PRO Avia 7/2584, PDS.

[22] PRO Air 14/1845, Mandrel used by Pathfinders outside main-stream was known as Carpet Sweeper.

also noticeably less.[23]

4. No 100 Group: On the Move

In December 1943, No 100 Group had conducted, with the few units at its disposal, a number of support operations for Bomber Command. By March 1944 there was pressure on Edward Addison from the Air Ministry and Sir Arthur Harris, to hasten the build-up of the Group to its authorised size and, in particular, to bring No 214 Squadron with its heavy Jostle IV jamming equipment, into the Order of Battle as quickly as possible.[24] No 214 Squadron had originally been a main force unit of No 3 Group, equipped with Stirlings, until in November 1943 Sir Arthur Harris withdrew all such aircraft from the front line during the Battle of Berlin. The unit was then selected for RCM work in No 100 Group. No 515 Squadron had already started to receive its Serrate equipment but, somewhat tardily, did not become operational until 5 March 1944.[25] On the 18th of that month, HQ No 100 Group moved to Bylaugh Hall, in Norfolk, which HQ No 2 Group had recently vacated, where it was to remain conducting bomber support operations until the end of the war.

At a meeting held at High Wycombe on 12 January 1944 to discuss the conversion of B17 aircraft to RCM platforms, those attending were informed that fourteen aircraft had been requested from the US 8th Air Force. In fact, the first B17F arrived on 20 January 1944 and by the end of the month the Squadron possessed a strength of ten aircraft. Each Flying Fortress had to be fitted with H2S, Gee or Loran, an API and AMU, a DR compass,

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[23] PRO Avia 7/2303; PRO Air 14/1962, App."E".

[24] PRO Air 20/1568.

[25] PRO Air 25/777.

Monica 111A, MF and HF, HF and VHF R/T communications, Jostle IV and four Airborne Grocers. Two weeks later a schedule of work was published for the lengthy conversion of each aircraft. A number of agencies were involved: some aircraft had to be flown to RAF Sculthorpe for crew conversion training on American aircraft; one aircraft went to TRE to act as a prototype for the interim RCM fit; other aircraft went to Scottish Aviation, at Prestwick, for the main prototype RCM to be installed; another went to RAE Farnborough for the fitting of Monica 111A, a tail-warning device, and navigation instruments before going to Sculthorpe for an interim RCM fit. Unfortunately, the schedule of work had to be revised because of the lack of RCM devices such as Jostle IV airborne jammers.[26] The small British radio industry was already swamped with orders from the three services for communications equipment; Metropolitan-Vickers, normally a manufacturer of heavy Electrical Equipment, had to be persuaded to manufacture the recently designed (by Dr Robert Cockburn) Jostle IV, which weighed about six hundred pounds. It took time to create a special design shop and fashion the necessary tools.[27] Prototypes had to be installed and six aircraft were earmarked to receive ABC devices instead of Jostle IV. These, however, were different from those installed in No 101 Squadron, in that each carried more than the three standard transmitters complete with six receiver/indicator units, compared with one such device fitted to the Lancasters.[28] The work started at the end of January 1944. It was during January, too, that the balance of No 214 Squadron arrived at Sculthorpe from Downham Market and was declared operational to

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[26] PRO Air 20/1563; PRO Avia 7/2212; PRO Avia 7/2213; PRO Avia 7/2214; PRO Avia 7/2215.

[27] Frank Rowlinson, *Contributions to Victory*, p.34.

[28] Martin Streetly, *Confound and Destroy*, p.39.

No 100 Group on the 17th of the month. Unfortunately, it was then discovered that the Flight Engineers of the Squadron had not received any air gunnery training. The authorities at RAF St Athan, responsible for the training of all Flight Engineers, had considered such a requirement unnecessary in mid-1943. Now, however, with the night fighter threat looming large, this omission had to be rectified, adding to the delay of conversion; appropriate training was conducted at RAF Sculthorpe.[29]

Arrangements had been made for a small US Army Air Force detachment, under the command of a Captain G.E. Paris, to assist with the conversion training of the crews of No 214 Squadron to the B17 Flying Fortress at RAF Sculthorpe. While this started off as a training commitment, efforts were made to integrate the US initiative into RAF operations, with the RAF providing the necessary specialist jamming equipment.[30] The US authorities were keen at this time to learn about countermeasures and to make maximum use of TRE designed equipment and thus the offer was accepted. On 10 February 1944, six crews, with their aircraft, arrived at Sculthorpe from the 96 Bomb Group (H) based at Snetterton Heath and on the 28 of the month the detachment became the 803rd Bombardment Squadron (P). A Major C.A. Scott became CO of the Squadron, taking over from Paris towards the end of April, before the move of No 214 and the 803rd to RAF Oulton. The US crews, however, had already completed a number of daylight bomber operations, and were now required to continue by night, and to take part with No 199 Squadron, in the Mandrel Screen. This was a radical change from dropping bombs in

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[29] Ron. P. Gadd, Ed., *Intercom*, (CBM Advertising, Liverpool, Spring 1993), pp.19-20.

[30] Martin Streetly, *Confound and Destroy*, pp.77-92.

daylight, and was not a popular move, especially amongst those crews who were due to be repatriated to the United States. The aircraft used in this new role for the 8th Air Force were equipped as follows: one B17 with Mandrel and three Carpet Jammers; two B17s with nine Carpet and four Mandrel Jammers; two B17s with six Mandrel Jammers, and one B17 ELINT Ferret with one S27 and one SCR S87 Receivers. [31]

Thus in February 1944 for the very first time, US Army Air Force aircraft were fitted with enough TRE-designed jamming equipment for the crews to participate fully in No 100 Group's specialist Bomber Support operations.[32] During the next eleven months Bomber Command's operations were to have the greatest effect on the Luftwaffe and although No 100 Group, under Edward Addison, was still expanding, it too was now about to enter its most effective period with a number of stations becoming operational.[33] RAF Swannington, located to the north of Norwich, opened on 1 May 1944, to become the home of two of the Group's Intruder Squadrons, Nos 85 and 157, and RAF Oulton, to the south of Swannington which, eight days later, became a full operational station. This latter location was earmarked to be the home of No 214 Squadron and the 803rd Squadron of the 8th US Army Air Force.[34] With them came the former Station Commander at Sculthorpe, Group Captain T.C. Dickens. During the early part of 1944, most of TRE, and not only the RCM Division, was more than fully engaged with tri-service preparations for the invasion

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[31] Ibid.

[32] Ibid.

[33] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.568.

[34] Martin Streetly, *Confound and Destroy*, pp.77-92; Mark K. Wells, *Courage and Air Warfare* (Frank Cass, 1955), p.5.

and thus could spare little time for No 100 Group per se. Up until then, the formation had benefited from the invaluable contribution made by TRE's Post Design Service (PDS), and loss of this facility contributed to No 214 Squadron's protracted conversion, along with the shortage of specialist jamming equipment.[35] In order to overcome this lack of technical support, Addison pressed successfully for creation of a Bomber Support Development Unit (BDSU).[36] This was formed at RAF Foulsham in Norfolk in April 1944, and, in addition to an establishment of nine Mosquito aircraft for operational trial purposes, it took over the workshop facilities at Radlett belonging to No 80 Wing.

5. Problems with the Return to Europe

Since Dunkirk in 1940, much thought had been given by a number of planning staffs and agencies, including TRE, to the return of a British Army to the Continent.[37] Sir Arthur Harris had hoped to avoid such an undertaking with the bombing of Berlin. Stalin was particularly insistent that such an invasion should have occurred as long ago as 1941; but the Germans remained too strong in Western Europe even with such a large commitment as the invasion of Russia.[38] The Prime Minister was well aware of the dangers to the United Kingdom if Stalin were to be defeated, or to arrive at an understanding with Hitler. Hence the Arctic convoys despatched at great cost, against Admiralty advice, to Murmansk and Archangel.[39] The Americans too, wanted to invade northern

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[35] PRO Air 20/1532.

[36] Martin Streetly, *Confound and Destroy*, p.208.

[37] PRO Air 20/8953, p.72.

[38] Martin Gilbert, *Winston S. Churchill*, vol.6, pp.1138-1139.

[39] Ibid., pp.1210-1213.

France and came up with a plan, Sledgehammer, in April 1942.[40] But the Allies were too weak, even if the numbers of ships and landing craft had been adequate. Such ventures required considerable air support and the then radius of action of fighter aircraft dictated that the landings in northern France could only take place in the Pas de Calais area or Normandy. Russian and American pressure led, on 19 August 1942, to the unsuccessful reconnaissance in force at Dieppe, during which a 5,000 strong Canadian contingent and RAF Fighter Command sustained the loss of 106 aircraft.[41] The excuse for the raid was to gain experience of an opposed landing over an open beach. Critics of the operation held that such knowledge had been acquired at Gallipoli during the First World War and that such an operation was unnecessary. The Canadians subsequently held Mountbatten, as Chief of Combined Operations, to blame for the inordinate number of casualties.[42]

The successful defence of El Alamein in North Africa, under Montgomery, in October 1942 and the subsequent counter-attack helped to check Field Marshal Rommel's eastwards dash to Cairo and beyond, and restore some pride to a battered 8th Army. This was followed a month later by the Anglo-American amphibious landings in Morocco and Algeria in North Africa, Operation Torch. These, however, could not be assisted by Radio Countermeasures based on allied territory; moreover, the landing beaches were beyond the range of German radar based in Europe. There was

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[40] Peter Calvocoressi and Guy Wint, *Total War* (Pelican Books, 1974), pp.334-335.

[41] Sholto Douglas, *Years of Command*, pp.173-175: Werner Rahn, ‘The War at Sea in the Atlantic and in the Arctic Ocean’ in Research Institute for Military History, Potsdam, Germany (eds.)G *Germany and the Second World War: Vol. VI, The Global War*, p.441.

[42] B.L. Villa, *Unauthorised Action: Mountbatten and the Dieppe Raid*, pp.46-47.

thus no requirement for a Radio Countermeasure Plan.[43] As a result of these successful operations, the Axis powers were eventually, and finally, driven out of North Africa, with all the attendant advantages that this favourable situation gave to the Allied powers in that particular theatre of War.

Much knowledge of amphibious landings was thus gained from these experiences. But it was a completely different matter with Operation Husky, the allied invasion of Sicily in July 1943. Here the Axis powers possessed an extensive network of Early Warning radars and aircraft fitted with AI and ASV. A comprehensive RCM plan was thus called for and successfully implemented; it went according to expectations and for the first time RCM became an integral part of a major Allied landing and, hence, an important precedent for the forthcoming landing in north-west Europe.[44] Meanwhile pressure, never far away, was increasing for a full-scale cross-channel invasion to be mounted in 1944. Indeed planning for such a venture had formally begun in April 1943, with the appointment of Lieutenant General F. Morgan, to the Chief of Staff Supreme Allied Command (COSSAC) organisation. Eisenhower was to become Supreme Commander at a later date.

6. TRE and Planning for Overlord

For Overlord to be successful much depended on the way the allied air forces were to be deployed, prior to the assault phase and during the actual invasion itself. In spite of the experiences gained from Operation Husky, Radio Countermeasures did not rate very

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[43] PRO Air 41/13, p.222.

[44] Ibid., p.227.

highly by the military planners and were either forgotten or overlooked in the early stages. Out of lengthy and heated discussion at high level came the Transportation Plan, involving the bombing of the German road and rail communications. It was adopted against the advice of Arthur Harris and Carl Spaatz, now commanding the 8th Army Air Force, and, only then, after a trial period when railway targets like Trappes in France and others in the Region Nord, was seen to have been successfully attacked by strategic bombers.

The staff at TRE also debated about how best to put a ground force ashore in France, on to heavily defended beaches. Indeed, discussions had begun just as soon as the cessation of the German aircraft Blitz against the United Kingdom permitted them to do so. As early as the autumn of 1942, a permanent invasion panel had been established at Malvern for the purpose, thereby facilitating an exchange of ideas within the Establishment and providing a potential source of essential RCM advice to service planning staffs.[45] The panel issued an interim report, but the three services took little interest in its contents or seemed unconcerned about RCM in spite of recent events in the Mediterranean. Inevitably, there was a high level of security surrounding the operation, which would normally exclude the personnel at TRE; but enough information became available for the panel to realise that planning for a major opposed landing on the continent in Northwest France, could generate demands for the highest level of technical assistance. Most importantly these might be made at the last moment. Unless, therefore, preliminary action was taken beforehand such help was unlikely to be forthcoming. In the

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[45] PRO Air 20/8953, p.72; PRO Avia 26/476; PRO Avia 26/477.

middle of 1943, the panel issued four papers outlining how radio techniques could assist with such a venture. One dealt with RCM in invasion and its use in mobile warfare. It included such cardinal points as the amount of effort necessary to find and accurately position the sites of German radar and radio aids; and the jamming cover required to neutralise such equipment, including the assistance that could be provided to support diversions and spoof attacks.[46]

Unfortunately, by the autumn, due to lack of interest in RCM only the most general of possible requirements had been forthcoming from service sources in spite of the best efforts of the panel, although it was well known that the invasion would take place the following year in 1944. TRE believed that, prior to an invasion, it would be essential to find the precise positions of the densely deployed German coastal radar stations along the occupied Continental coastline with the aid of accurate Direction Finding. The Y-Service, however, were not convinced that such a survey would be useful. On A.P. Rowe's own initiative, therefore, work was started in 1943 on the development of precise ground D/F equipment, known as Ping Pong, essential to the location of German radar sites and on the airborne Homing device Abdullah.[47] In 1944 the need for Ping Pong was accepted and TRE was able to provide D/F stations giving an accuracy of one quarter of a degree on the decimetre frequencies, and one half a degree on the Freya frequencies.[48] Moreover, attention was paid to the radar detection

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[46] TRE Report T1471 dd. 11 June 1943, The use of RCM in Invasion and Mobile Warfare, quoted in PRO Air 20/8953, pp.72-73 and App 1; PRO Avia 7/476; PRO Avia 7/477; PRO Air 20/8953, pp.72-73 and App. 1.

[47] PRO Air 20/8953, pp.72-73.

[48] PRO Air 20/8953, p.15.

of ships and associated jamming problems; at the same time the opportunity was taken to test Moonshine in a maritime role.

On 12 January 1944, less than six months before D-Day, the Chief Signals Officer, Allied Expeditionary Air Force, visited TRE to ask formally for assistance.[49] Subsequently, Dr Robert Cockburn was given the necessary security clearance; and, attached to the D-Day planning staff; he became privy to the highly secret invasion plans. In the time available, this direct contact was the only way some of the highly intricate problems that arose could be thrashed out and appropriate solutions found. By now, however, time was so short that if preliminary action had not already been taken by TRE, in advance of the requirements finally agreed, they would not have been provided. The landings could then have been placed in jeopardy. Even so, it took a Herculean effort by the 100 strong RCM Division, located in House 7 at Malvern, to ensure that a RCM plan was developed and the necessary equipment produced in time (See Figure 16). Indeed, it was only by drawing on the resources of the entire Establishment that the programme was successfully completed by the date of the invasion.[50]

Tactical surprise was essential, as was the prevention of German army reserves moving to the invasion area. In order to achieve these aims, it now became obvious that accurate Y information on the location of German radar sites was required (See Figure 17), and this information was largely acquired through the use of Ping Pong, and Coalscuttle, an airborne D/F system employed in detecting frequencies above 1000 Mcs; and Bagful, an automatic search receiver which recorded the radio frequency of

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[49] PRO Air 20/8953, pp.72-73.
[50] Ibid.

R.C.M. DIVISION – JUNE 1944

DR. R. COCKBURN

G.W.G. Court - TO

J. Hardwick - SSO

Group 3

- B. Russell ... SSO
- R.S. Wilson ... SO
- K.G. Gillard ... SO
- J.H. Bruce ... SO
- D.L. Leete ... TO
- R.H. Garnham ... JSO
- J.F. Hogg ... JSO
- F.A. Higgins ... AII
- F.J. Nickel ... AII
- P.R. Buckland ... AIII
- R.S. Cambray ... AIII
- P.S. Henderson ... AIII
- E. Jamieson ... AIII
- M. Greenhill ... AIII
- P.O. Levers ... AIII
- J.R. McCulloch ... AIII
- W.H. Parry ... AIII
- G.J. Parish ... AIII
- P.A. Sturrock ... AIII
- J.E. Turner ... AIII
- F. Holt ... AIII

Group 5

- M. Ryle ... SO
- T.G. Thorne ... SO
- P.D. Hall ... SO
- G.F. Newell ... TO
- D.W. Briscombe ... TO
- J. Warburton ... TO
- D. Maurice ... JSO
- G.D. Morgan ... JSO
- A.C. Robertson ... JSO
- G. Greenlees ... JSO
- V. Russell ... AII
- L.P. Garland ... AIII
- W.J. Norman ... AIII
- A.M. Wildblood (Miss) – AIII
- G. Wood ... AIII
- F/Lt Steed

Group 6

- W.E.J. Farvis ... SO
- J. Curran (Mrs) ... SO
- R.G. Silversides ... SO
- W. Fishwick ... SO
- F. Schofield ... JSO
- C.B.G. Taylor ... JSO
- L.A. Moncrieff ... AII
- L.E. Pulford ... AII
- G.W. King ... AIII
- W.St J. White ... AIII
- E.G. Sandels ... AIII
- V. Tweedie (Miss) ... AIII
- F/O Bradwell

Group 14

- E.H. Cooke-Yarborough ... SO
- R.P. Chasnar ... SO
- C.D. Florida ... TO
- J.F. Forster ... TO
- N.D. Belham ... TO
- J.O. Newton ... JSO
- I.A. Bagnall ... AIII
- L.H. Brown ... AIII
- M. Bilborough (Miss) ... AIII
- B. Forbes (Miss) ... AIII
- A. Rollins ... AIII
- F/Lt W.J.J. Curry ...

Group

- J. Stewart ... STO
- J.L. Bliss ... SO
- D.J. Allen-Williams ... SO
- C.T. Holland ... TO
- I.G. Morgan ... TO
- T.S. Moss ... JSO
- H. Gent ... JSO
- J. Brinkworth (Miss) ... JSO
- J.F. Turner ... JSO
- D.W.F. Mayer ... JSO
- H.L. Aldar ... JSO
- J.H. Balding ... AII
- G.C. Scorgie ... AII
- D.W. Slimming ... AII
- F. Hart ... AII
- E. Mackenzie (Miss) ... AIII
- E. Ford ... AIII
- R. Jameson ... AIII
- W.L. Murray ... AIII
- F/Lt Niald

DO

- B. Hewins

W/S

- F/Lt Brunt

P.D.S. (Group 25C)

- D.A. Parry ... SO
- L. H Orton ... SO
- V. Roberts ... JSO
- D.I. Stretton ... AIII
- J.C. Bray ... AIII
- A. Hewish ... AIII
- B.A. Muddle ... AIII
- J. Campbell ... AIII
- S/Ldr Clarkson
- F/Lt Johnstone
- F/O Senior
- F/O Sheppard
- F/O Mackenzie
- F/O Morris
- F/O Whitmore

Divisional

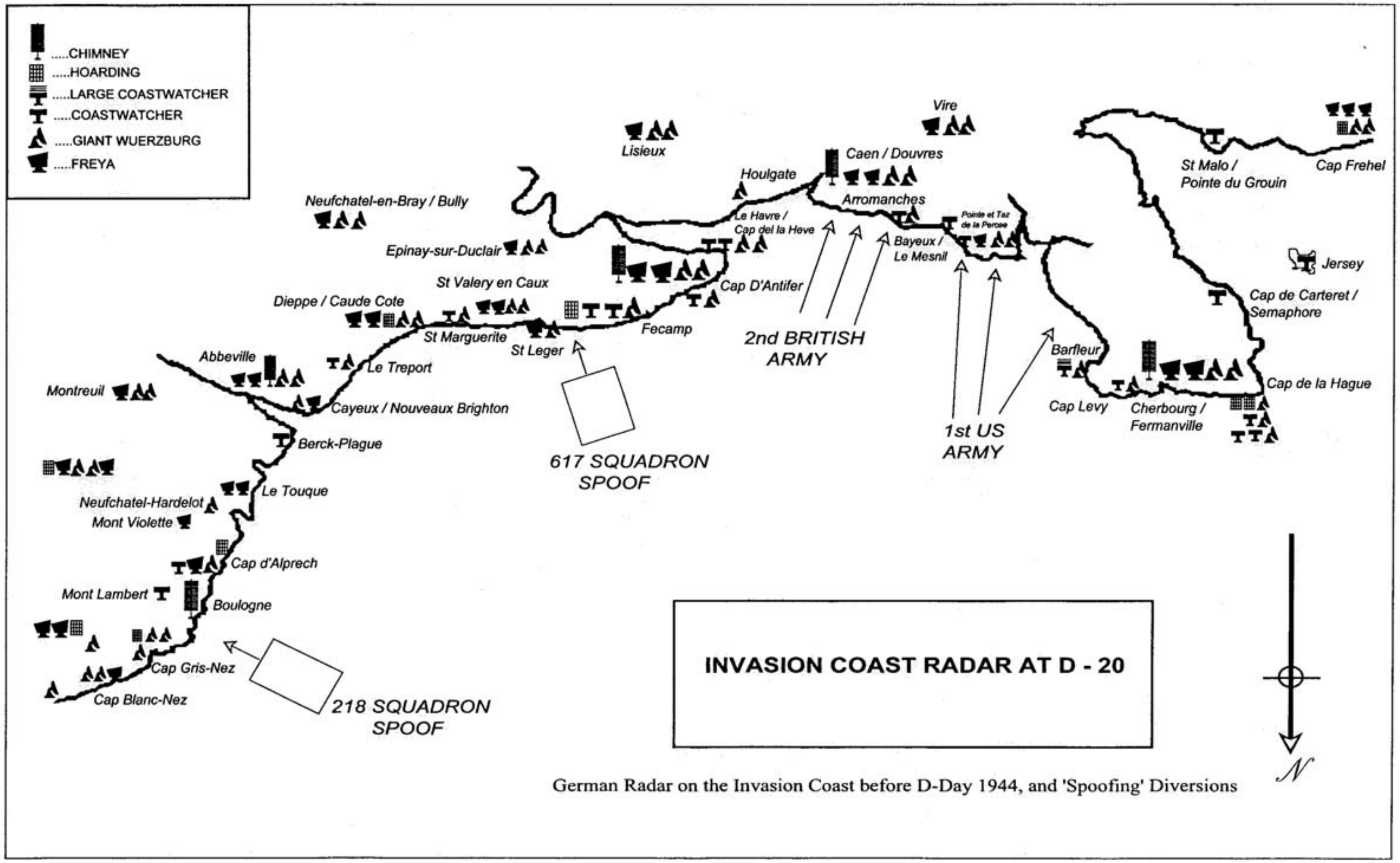
- J. Jefferson ... SO
- L.O. Rogers ... AIII
- T. Gerrard ... AIII

D.O.O.

- L.J de B Breed AIII

Air 20/8953

Figure 16
T.R.E. R.C.M. Division



R.V. Jones

Figure 17
German Radar to D-Day

German signals and the time of interception.[51] Moreover, direct attacks were considered by fighter aircraft against selected German radar positions with the aid of Abdullah. Prevention of detailed observation by the Germans of the allied invasion convoys and accurate shore-based gunfire was also necessary, and this was to be achieved through use of Mandrel 1 and Mandrel 3, together with Carpet 2; TRE being the design authority. To mislead the Germans, shipping diversions were planned by TRE with the aid of radar, and it was calculated that the protection of the Allied airborne forces from interception by Luftwaffe fighter aircraft could be achieved through the combined use of Window, airborne Mandrel and Air and Ground Cigar.[52] In preparation for the actual landings, however, TRE had long developed communications jamming equipment. As far back as 1941 the RCM Group had produced Jostle II, which was used in the Middle East on at least two occasions. But during 1942 not so much attention could be given to the planning of Overlord, even if TRE had been wanted by the Overlord planning staffs, as it had been fully employed, or nearly so, in helping the RAF to maintain the bomber offensive. The following year, however, was a different matter.

During August 1943, TRE had entered into discussions with Air Defence of Great Britain (ADGB), formerly Fighter Command, about the invasion plans, when it was disclosed that German radar stations were to be attacked.[53] Existing Y-Service equipment was incapable of the accuracy required for such a purpose, or even of handling the volume of data expected. In consequence, during the

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[51] PRO Air 14/2928; PRO Air 14/2933.

[52] PRO Air 20/8953, p.74.

[53] Ibid.

previous autumn, TRE had constructed two mobile trailers designed to house the necessary Ping Pong equipment, which covered a frequency range of 300-600 Mcs. Trials involving the trailers failed to take place, but close examination of the characteristics of German transmissions revealed that it would be better to rely on radio frequency for identification, rather than recurrence frequency. Modified Bagful equipment was also installed in the trailers, thus providing a highly accurate recording frequency meter. This obviated the necessity for a communications link between pairs of trailers and to some extent offsetting the lack of trials. Early the following year, construction of four more trailers started in TRE workshops and on 1 March 1944 an experimental watch with Ping Pong started at Ventnor, Isle of Wight. As late as February 1944, the Allied Expeditionary Air Force RCM Plan had confirmed the necessity for more accurate Y facilities and, as a result of a formal request by the RAF Y-Service on 9 March 1944, for more trailers, five were constructed by strenuous efforts in TRE's workshops. These were positioned on site at Acton, Ventnor and Beachy Head by early May 1944.[54] But for previous TRE initiative there would have been little hope of providing this equipment.

RAF signals personnel had been trained to operate Ping Pong but it was proposed that, as a precaution, TRE specialists should remain on site during the actual invasion. As a result, the precise information furnished by Ping Pong enabled many German radar stations located in the invasion area, to be destroyed by bombing before the actual assault. Confirmation that these attacks had been successful came when few supplementary sorties were

[54] PRO Air 20/8953, p.75.

required.[55]

Late in May, a report was received of a German transmission in the 2000 Mcs range. By working throughout Whitsun, TRE and RAF Defford personnel managed to install appropriate Coalscuttle equipment in an aircraft and, within three days of the news, the crew concerned was able to report that the Luftwaffe had decided not to resort to the use of new frequencies in the microwave region and for which no jamming measures had been prepared.[56] In January 1944, when the original RCM plan was agreed, the success of Ping Pong could not have been foreseen. Almost certainly it would not have been of much use if the Germans had opted for mobile radars. Moreover, visual location of the smaller Wurzburg would not have been possible in poor visibility. It was therefore proposed that rocket firing Typhoons would be employed, fitted out with the Abdullah homing device, against Wurzburg installations. Because this equipment was technically quite difficult to use, requiring much practice and, in view of the strong anti-aircraft defences surrounding most German radar sites, it was decided not to begin this particular method of attack.[57]

7. RCM and Overlord

Because of the adoption and implementation of the Transportation Plan, when D-Day dawned some eighty targets had been attacked with the result that the Wehrmacht was finding difficulty in moving troops and supplies by rail in a large part of Northern France and Belgium. This lack of mobility was to prove a major hindrance for the German armed forces. Aircraft of the Allied

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[55] R.V. Jones, *Most Secret War*, p.408.

[56] PRO Air 20/8953, pp.75-76.

[57] Ibid.

Tactical Air Forces, which came directly under the Supreme Commander at SHAEF, were responsible, among other tasks, for paralysing the sixty-six German radar stations situated between Dunkirk and Brest; for security reasons, care was taken to attack twice as many radar stations outside the immediate landing area as inside. The undertaking, however, could not be completed before D-Day and thus resort had to be made to radio countermeasures under the able direction of AVM Victor Tait, the RAF Director General of Signals at the Air Ministry. But for the initiative taken by Dr R.V. Jones, however, it is doubtful if Victor Tait would have been appointed to the AEAF in time, if at all.[58]

The invasion beaches almost chose themselves once it was appreciated that the landing area had to be within range of UK based fighter aircraft. Thus after Normandy had been selected, it became a matter of persuading Hitler and his generals that the actual invasion would occur elsewhere, say in the area of Calais, or perhaps the mouth of the Somme which flowed into the Channel near Abbeville, or even east of the Seine.[59] Hitler, himself, believed that the invasion would come between the river Seine and the river Scheldt; the area where he had most of his defensive wall built.[60] Deception, therefore, became paramount and the seaborne feints in that area Operations Taxable and Glimmer were designed for just that purpose.[61] The naval RCM plan was the responsibility of the Admiralty Signals Establishment (ASE), although there was close collaboration with TRE. At the time it became obvious that a more

[58] R.V. Jones, *Most Secret War*, pp.401-402.

[59] Adolf Galland, *The First and the Last*, p.282.

[60] Richard Overy, *Why the Allies Won*, p.153.

[61] PRO Air 20/8953, p.76.

accurate theory of the surface detection of ships by radar, was required, if the effect of shipboard jamming was to be properly addressed. Thus a new conception of the characteristic radar echoes of ships was placed on a firmer basis and, in January 1944, the information was issued to those concerned and formed part of the Admiralty Signals Establishment RCM plan.[62] The equipment used by the Royal Navy included RAF Carpet 2, Mandrel 1 and Mandrel 3, together with United States jammers.

The invasion convoys assembled at Portsmouth, Southampton and Plymouth and these concentrations of ships were potentially open to surveillance by German reconnaissance aircraft. In fact, effective air reconnaissance by the Luftwaffe of the embarkation ports and shipping was found to be impossible, because of allied air superiority.[63] In any case the Germans were not to know the precise destinations of the assembled shipping from any photographs obtained. The D-Day planners, therefore, decided to send two diversionary forces in order to simulate attacks in the area of Dieppe and Boulogne. Large numbers of actual ships were obviously not available for this purpose but, nevertheless, any simulation had to be comparable with the actual convoys. It was, therefore, decided to exploit German reliance on radar by simulating large convoys on German radar screens. While this subterfuge could be exposed by visual sightings from the air, plausible and precise spoof information was unlikely to be ignored. And so it proved to be, as the Luftwaffe was content to supplement almost completely neutralised ground radar with a modicum of

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[62] Ibid.

[63] Adolf Galland, *The First and the Last*, p.283.

ASV patrols. Thanks to Allied air superiority, no visual sightings of allied shipping occurred of any consequence.[64]

Jamming alone was not enough, however, because of the small amount of shipping which was available for this task. Moreover, the jamming cover for the main assault shipping would almost certainly be incomplete, enabling the Germans to obtain an occasional radar picture. The Neptune planners thus decided that similar plots should be provided by the diversions. Consequently, a small number of light naval craft were detailed for the task, each carrying both a balloon in order to increase the range of detection by the Germans, and a special type of Moonshine. This was designed by TRE to produce the effect of a large formation of shipping to Luftwaffe Air to Surface Vessel radar. Moonshine, however, could not cover the full German radar spectrum and therefore aircraft were to drop Window very accurately in order to simulate the slow advance of a large convoy. At the same time, the Royal Navy were to provide a plausible amount of jamming but insufficient to conceal the remainder of the spoof. Lastly, loudspeakers were to broadcast noises of a fleet anchoring offshore at the appropriate time.[65] TRE had hoped that the original Moonshine equipment, used by aircraft of Fighter Command in 1941, would suffice for this operation, even if it had to be modified. Trials at Tantallon in Scotland, however, revealed the need for a complete re-design. With assistance, the RCM Division of TRE prepared twelve sets for use against the Luftwaffe's Hohentwiel ASV radar, operating on a frequency of 560 Mcs, and six sets covering the 90 Mcs band. All were tested satisfactorily at

[64] PRO Air 20/8953, p.77.

[65] Ibid.

Tantallon, by the end of April. Meanwhile, TRE was training US Army Signals personnel who had recently arrived from Iceland. A very high standard of operating was required, in order to deal with the many contingencies that were likely to arise.

With no previous experience, the American operators subsequently acquitted themselves well.[66] Only four of the Moonshine fitted launches were available for D-Day operations and three were allotted to the Taxable operation at Cap d'Antifer and one to Boulogne, Operation Glimmer. Fortunately from the allied point of view, German ASV observed both Taxable and Glimmer, which were found to have the correct radar characteristics of an invasion fleet, by a Luftwaffe standing patrol in the Straits of Dover and ASV reconnaissance in the invasion area itself. This was precisely what was intended to happen. The transmissions were effectively Moonshined and a log maintained in spite of the operators suffering from seasickness, a small but none the less important consideration.[67] On this occasion Window was used in the reverse of its normal role. It was employed to simulate rather than conceal the movement. The amount of Window needed to simulate a target at sea level was small. It required eight aircraft dropping a special type of Window, in accordance with a carefully prescribed pattern, in order to cover the approach of an invasion fleet occupying a sea area of sixteen by sixteen miles. Because of the difference in speed between a ship and an aircraft, exact navigation was essential. This would be possible with the use of such aids as Gee and G-H. The aircraft were required to fly a series

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[66] Ibid., p.78.

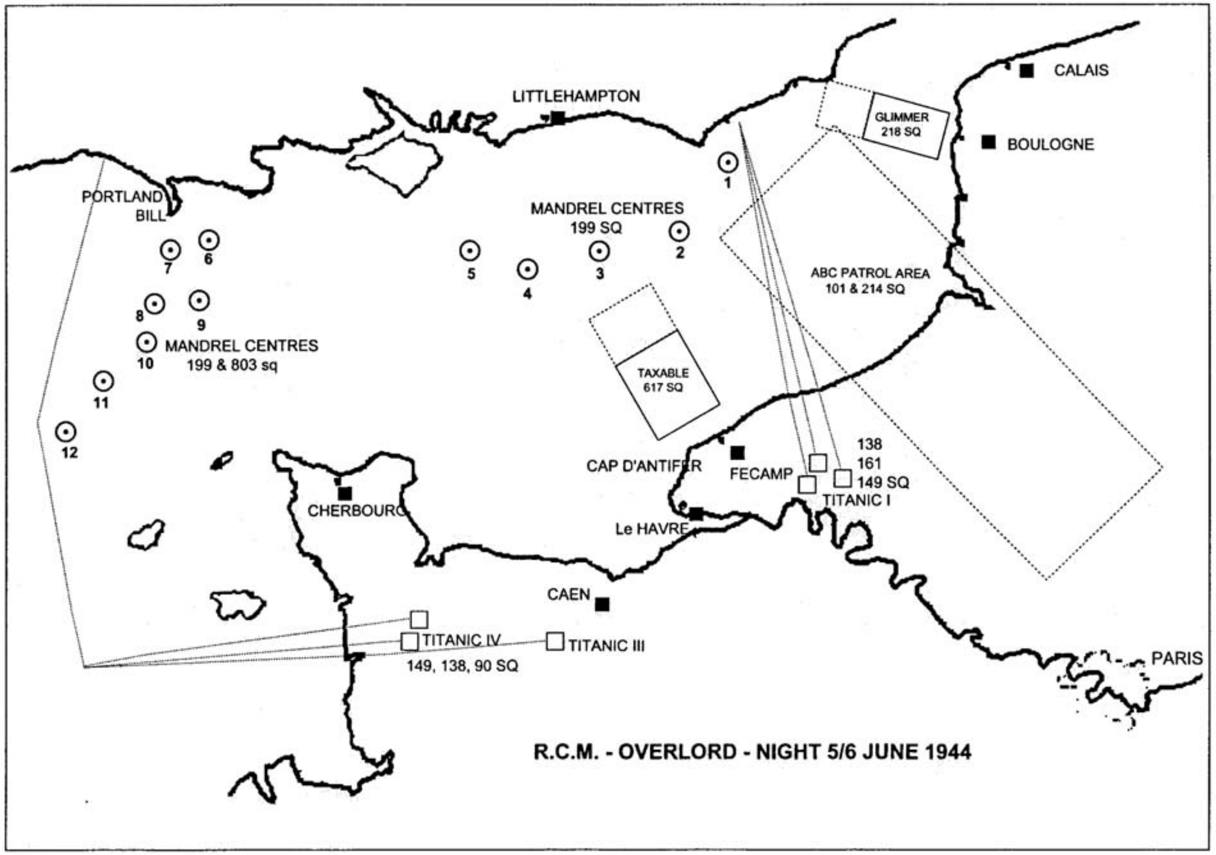
[67] TRE Report 5/M/45/RC dd.13 June 1944, The Moonshine Operation of 6-7 June 1944, quoted in PRO Air 20/8953, App.“1”, p.11.

of patterns, similar to a racecourse, turning at the front of a spoof convoy, which advanced at a speed of exactly seven miles an hour. The rate at which the various types of Window were dropped also required careful consideration and had to be strictly related to the movement of aircraft.

Obviously, special training was required but, because many of the aircraft concerned were heavily engaged in implementing the Transport Plan, the allocation of aircraft was not made by Bomber Command until five weeks before D-Day. This did not allow much time for rehearsals. None the less, No 218 Squadron from No 3 Group was assigned to Glimmer and used the G-H station at High Street for track guidance and Gee lattice lines from Canewdon and Truleigh Hill to determine the turning points. From No 5 Group came No. 617, the Dambuster Squadron, which was allocated to Taxable and used Gee, which was accurate enough for the purpose in this area. Both operations were subsequently conducted satisfactorily according to plan and without loss. Glimmer drew a lot of attention from the German naval shore defences and from E-Boats. Taxable was closer to the main assault area, where most German radar was probably destroyed (See Figure 18). Thus this spoof may have escaped observation completely.[68]

In addition, two large formations of slow, unarmed transport aircraft full of airborne troops had to be protected. Three methods were decided upon; intensive jamming from the air of the German Freya and Chimney installations, provision of a Window diversion and intensive airborne jamming of the Luftwaffe night fighter force. A special Mandrel Squadron, No 199 from No 100 Group, was

[68] PRO Air 20/8953, p.79.



RCM cover for Operation 'Overlord' - 5/6 June 1944

RCM cover for Operation 'Overlord' - the Allied invasion of France - consisted of five seperate operations:

1. 'Taxable'
2. 'Glimmer'
3. 'ABC'
4. 'Titanic'
5. 'Mandrel'

'TAXABLE'
A combined naval and air diversion against Cap d'Antifer with 16 aircraft from No. 617 Squadron RAF

'GLIMMER'
As with 'Taxable', 'Glimmer' was also a joint naval/air operation but against Boulogne. No 218 Squadron RAF provided six aircraft

'ABC'
Operations consisted of 24 aircraft from No 101 Squadron RAF along with five aircraft from No 214 Squadron providing VHF jamming support for Operation 'Taxable' and 'Glimmer'

'TITANIC'
'Titanic' consisted of 34 aircraft from Nos 90, 138, 149 and 161 Squadrons RAF, which provided three feint airborne attacks towards Caen.

'MANDREL'
The 'Mandrel' screen was provided by 16 aircraft from No 199 Squadron RAF, and four aircraft from the 803rd Bomb Squadron USAAF , consisting of two screens with 12 centres.

Sigs1 HQ BC

Figure 18

R.C.M. Plan - 'Overlord'

employed against the Early Warning radars with new Mandrel 3 jammers. The Window diversion details became the responsibility of the Operational Research Section (ORS) at Headquarters Allied Expeditionary Air Force (AEAF), and Air and No 80 Wing's Ground Cigar took care of the German night fighter communications. Little additional work was required for this last commitment, as Bomber Command already possessed No 101 Squadron with ABC and No 80 Wing was well experienced in the use of Ground Cigar. A high-power jammer was positioned at Brighton in case it was required, but because of the dangers of interference to allied communications it was not used on this occasion.[69] No 80 Wing had been asked to provide full countermeasures during the preparations for the actual assault and throughout the subsequent campaign, which was to be fought in Normandy.[70] Indeed, part of the Neptune Plan involved the formation providing RCM protection for the invasion ports and for the provision of a number of mobile units, which it was intended should operate from the Continent, thereby furnishing cover for the Normandy bridgehead and, eventually, protection for the port of Cherbourg. In the event, accurate bombing and large-scale fighter attacks by Luftwaffe aircraft against the allied landings failed to materialise. No beam activity was identified and R/T control of German aircraft was negligible.[71] The fighter element of No 100 Group also played a prominent part in covering the landings, including the Mk XVII

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[69] TRE Report T18475/R/1199/MR/LM dd.24 April 1945, Mandrel 3, quoted in PRO Air 20/8953, App."1", p.7.

[70] PRO Air 41/46, pp.62-64.

[71] Ibid.

Mosquitoes of 85 Squadron and the Mk XIX Mosquitoes of 157 Squadron.[72]

No 214 Squadron had become operational in April 1944, but since then had moved to Oulton and it was thus from this Station that No 214 and the American 803rd Squadron made their contribution to D-Day. On the night 5-6 June 1944, 214 provided five B17 Flying Fortress aircraft, with ABC Jammers in lieu of Jostle IV, and considerable quantities of Window. The Fortresses joined with No 101 Squadron on this occasion, the crews having been briefed to fly along a line parallel to the River Somme, in order to produce a significant airborne barrage of jamming.[73] This comprised eighty-two ABC Jammers, designed to distract and blind the German radar screens from the passage of about 1,000 slow-flying and vulnerable Allied transport aircraft, carrying parachute troops and towing glider-borne troops. The task of the two contingents was a vital one, for it was to secure the left and right flanks on the ground of the allied armies in Normandy. One of the RAF Fortresses was flown by the unit's Commanding Officer, Wing Commander D.G. McGlinn. This officer was flying a six-and-a-half-hour sortie when his aircraft was attacked by a Me 410. His rear gunner, the Squadron Gunnery leader, Eric Phillips, opened fire and shot the German aircraft down.[74] Conspicuously, this was one of the very few German aircraft to penetrate the Window cloud being disgorged by both Squadrons on this day.

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[72] Martin W. Bowman and Tom Cushing, *Confounding the Reich: The Operational History of 100 Group (Bomber Support) RAF*, p.54.

[73] William B. Breuer, *Hoodwinking Hitler*: *The Normandy Deception*, (Praeger, Westport, Connecticut, 1993), p.201.

[74] Murray Peden, *A Thousand Shall Fall*, pp.382-384. Peden was a Canadian pilot with No 214 Squadron and at RAF Oulton 1944-1945;.Martin W. Bowman and Tom Cushing, *Confounding the Reich: The Operational History of 100 group (Bomber Support) RAF*, p.89.

Ironically, however, a Lancaster of No 101 Squadron, from No 1 Group, was lost on the same patrol, but the crew was saved.[75] Moreover, for the first time twelve airborne Mandrel jamming centres were provided on D-Day, by No 199 Squadron of No 100 Group and the US Army Air Forces 803rd Squadron. These stretched from Littlehampton to Portland Bill, and were well backed-up by the ground jammers of No 80 Wing, all aimed at the German Early Warning radar system in the 90-200 Mcs band. The new MB type of Window, developed by TRE, was used operationally for the first time against the Freya Early Warning radars.[76]

8. Air Superiority

The allied air forces available to support the landings on 6 June 1944 amounted to some 6,000 to 7,000 aircraft. At best, the Luftwaffe opposing them numbered some 319, a ratio in the allies' favour of about 20:1. Of these German planes, however, only a hundred were actually fighter aircraft.[77] The allied landings in Normandy were thus successful, thanks largely to this massive air superiority. The Luftwaffe never seriously challenged the allied air forces on 6 June 1944, although plans had long been drawn up to send fighter reinforcements to France from the Reich home defence squadrons. But, because of the element of surprise, the uncertainty surrounding the extent of the actual assault, and the possibility of landings occurring elsewhere in France, the orders transferring almost all the Luftwaffe's home defence fighter force were delayed until 7 and 8 June 1944. At full strength, the reinforcements should have amounted to some 1,100 aircraft, but

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[75] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.523.

[76] PRO Air 14/1962, pp.142-143.

[77] Adolf Galland, *The First and the Last*, p.284.

the units were not at full strength for a number of reasons, such as the severity of the allied bombing campaign, the interruption of communications and the chaotic state of French airfields. The result was that only two hundred and eighty-nine German fighter aircraft were available in France for operations on the night 7 June 1944.[78] Even so, the Allies were lucky, that when a few night fighters were scrambled in the early hours of 6 June, they were vectored to the east between Amiens in France and Deelen in Holland. Had they turned to the west they would have found the unarmed gliders and the airborne forces.[79]

9. Dispersal: Post–Overlord

Of the Squadrons which contributed to the D-Day's RCM activities, No 218 reverted to No 3 Group and main force operations, No 617 (the Dambuster Squadron) of Operation Taxable reverted to main force as a precision bombing Squadron with No 5 group, No 101 continued with its critical ABC role within No 1 group and No 214 Squadron returned to No 100 group to be employed in a greatly enlarged RCM role. The sixteen aircraft of No 199 Squadron also reverted to No 100 group where it was shortly to be employed on expanded Mandrel Screen duties. The Operation Titanic Force, which dropped dummy parachutists, returned to No 3 Group, although No 138 Squadron continued for a time to be employed on Special Duties operating from RAF Tempsford, under the auspices of No 38 Group. From the knowledge and experience gained from the D-Day operations, No 100 group, under its AOC AVM E.B. Addison, was by July 1944 now in an ideal position to provide much more effective support to

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[78] Donald Caldwell, *JG 26*, p.243.

[79] William B. Breuer, *Hoodwinking Hitler: The Normandy Deception*, p.199.

Main Force than hitherto, and thus make a major contribution to reducing its current loss rate, which had risen to well over 6%.[80]

Summary

The Bomber Command attacks on Berlin continued well into 1944, with varying degrees of success. There was still much to learn, however, about support to the bomber stream in the form of Serrate Patrols and tactical diversions. Much hinged on up-to-date intelligence of the German night fighter organisation and thus an attempt was made to make better use of the information coming from Enigma, the Y-Service and No 101 Squadron, which was kept very busy indeed conducting electronic eavesdropping. Co-ordinating all this information and being able to make the best tactical use of it, however, took time. Nevertheless, Bomber Command did hit Berlin hard, although the much hoped for shortening of the war did not materialise. Big Week, or Operation Argument, was a US Army Air Force operation, designed to knock-out the German aircraft industry. It started on 20 February 1944 and although it did not succeed in its aim, there is little doubt that the German aircraft industry was badly damaged. More importantly, many Luftwaffe pilots and fighter aircraft were lost during the six days of intense strategic bombing and this was to contribute greatly to the Allies obtaining air superiority.

Germany reacted to all this activity by quickly repairing the damage done to the aircraft industry, enabling the day and night fighter force to be strengthened; and in response to No 100 group's RCM measures, the original Freya frequencies were enlarged. Much use was also made of the Luftwaffe tracking service, their task

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[80] PRO Air 14/1962, Part V, graph No 5A.

being made easier by the Main Force use of IFF, H2S and other active devices. Fortunately, Drumstick was available to counter the use of HF W/T transmissions, which were being used to provide running commentaries for the benefit of the German night fighter organisation. Similarly, when Luftwaffe instructions began to be passed by VHF R/T in the 31.2 Mcs band, three ABC transmitters were used as jammers quite effectively. During this period the Luftwaffe obviously considered RCM to be a threat to the night defence organisation and sought to control their aircraft by every available means. Generally No 100 Group were able to counter these moves, except for the reduction in the success rate of Serrate interceptions. The solution to this problem had to wait until July, after the invasion, when a Ju 88 complete with a working SN-2 landed in the United Kingdom, through Meaconing action. A new type of Window was then deployed and used successfully, firstly against Kiel later the same month. The conversion of No 214 Squadron proved to be a protracted affair, mainly because of a shortage of specialised jamming gear. Nevertheless the unit was converted successfully and completed its first operational sortie in April. The US Army Air Corps Squadron, the 803rd, grew out of No 214's conversion unit and such was the desire on the part of the Americans to learn as much as possible about RCM, and the techniques involved, that the 8th Air Force agreed to the unit participating in Bomber Command's operations, which it did for the first time in June.

It was fortunate for RCM in general, and the military in particular, that TRE had long been interested in an Allied return to Europe. The Establishment had thus produced a number of pertinent papers on the subject, but without arousing much interest amongst the military planning staffs. After all, RCM had not been used during Operation Torch and no detailed post mortem had been conducted into the results of jamming, after the assault on Sicily. Operation Husky could well have provided the precedent required by the D-Day planners. Ping Pong subsequently proved to be a great success, especially when used in conjunction with other TRE designed instruments. Late in January 1944, TRE was formally asked for assistance with the Normandy landings; this request would have been too late if TRE had not taken action earlier. In April, the Transportation Plan had been adopted and some eighty appropriate targets had been attacked successfully prior to the assault-taking place. This was to make moving German personnel and supplies towards Normandy extremely difficult and prove a major disadvantage for the German Army. In addition, it was planned to bomb the sixty-six German radar stations, which might have been used to detect the movement of the allied invasion forces. This task, however, could not be completed in time and, to fill the gap, it was decided to use RCM. In this way RCM helped to keep the Germans guessing as to where the main landings were to take place.

Both diversions were successful, as were the airborne RCM measures put in place to safeguard the two fleets of air transports, which carried the first troops to land on the Continent and thus open the Second Front. The RCM Plan was completed as planned. In spite of the massive amount of air cover provided, the allies were lucky on D-Day when the Luftwaffe put up very little opposition. Partly this was due to poor communications and to the wide dispersal of aircraft throughout France, made necessary in order to escape the effect of allied bombing. Reinforcements from Germany then failed to reach the West in time to oppose the actual landings. When they did start to arrive the following day, the German fighter squadrons involved were found to be well below strength. In order to be able to judge just how large a force No 100 Group had become since November 1943, and to show how hard the Group

Staff had worked, the Order of Battle for December 1944 is set out in the list below:

HQ No 100 Group, Order of Battle, December 1944.

No 141 Mosquito Sqn. RAF West Raynham, Serrate.

No 192 Halifax Sqn. RAF Foulsham, Electronic Surveillance.

No 169 Mosquito Sqn. RAF Little Snoring /Great Massingham, Serrate.

No 239 Mosquito Sqn. RAF West Raynham. Serrate.

No 515 Mosquito Sqn. RAF Little Snoring, Intruder.

No 214 B17 Fortress Sqn. RAF Oulton, Heavy Jamming, Jostle IV, Piperack, Carpet and Window.

No 199 Stirling/Halifax Sqn. RAF North Creake, Mandrel and Special Window Force.

No 85 Mosquito Sqn. RAF Swannington, Low and High level Intruder.

No 157 Mosquito Sqn. RAF Swannington, Low and High Level Intruder.

No 23 Mosquito Sqn. RAF Little Snoring, Intruder.

No 223 B24 Liberator Sqn. RAF Oulton, Heavy Jamming, Jostle IV, Piperack, Carpet and Window.

No 171 Stirling/Halifax Sqn. RAF North Creake, Mandrel and Special Window Force.

No 462 Halifax Sqn, RAF Foulsham, Window and Airborne Cigar. Special Window Force.

In this chapter No 100 Group has been examined and its successes and failures described. The contribution made by TRE to the radio war has been studied and its invaluable role described. The next chapter investigates events after D-Day and includes the Luftwaffe's V1 flying bomb and the German army's V2 rocket campaigns.

CHAPTER NINE: EVENTS AFTER D-DAY

1. Allied Bomber Operations

During the 24-hour period immediately before the landings on 6 June 1944, Bomber Command, under the direction of the Supreme Commander, had completed 1,211 sorties, at the time a record for one night and, understandably, mostly conducted in support of the land forces.[1] Targets comprised, and continued to comprise for the ensuing ten weeks, concentrations of German troops, ammunition dumps, gun positions, and stores and supplies, together with the now routine road and rail communications.[2] Bad weather in August 1944 then restricted air operations over the next fortnight, but assistance to the land forces was soon resumed. With capacity to spare, it was also found possible to revert to attacking oil refineries and the synthetic oil industry. Indeed, Sir Arthur Harris had been asked to do this by General Eisenhower.[3] Powerful forces were available for the task and they included 2,100 heavy bombers of the 8th Air Force, 1,100 heavy bombers of Bomber Command and 1,200 heavy bombers of the 15th US Air Force, based in Italy. Against such large air fleets the depleted Luftwaffe fighter force was heavily outnumbered,[4] although efficient fighter production soon made good the losses. Fuel, however, was another matter, stocks fluctuating wildly in accordance with bombing patterns. The outlook for Germany in July and August was grim, however.[5] Sir Arthur Harris even

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[1] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.521.

[2] PRO Air 14/1962, pp.23-25.

[3] PRO Air 14/1962, p.200.

[4] Adolf Galland, *The First and the Last*, p.292.

[5] Albert Speer, *Inside the Third Reich*, pp.473-474.

resumed daylight operations. But as was to be expected, collateral damage and casualties amongst the French populace remained uppermost in the Commander-in-Chief's mind. Full advantage was thus taken of the RAF blind bombing aids, Oboe and G-H, which offered the best chance of placing the bombs close to the target, especially in poor weather conditions.[6]

The first target to be selected for attention in the new allied oil campaign by Bomber Command was located at Gelsenkirchen, the attack occurring on the night 12-13 June 1944. The German Controller was able to direct his night fighter force accurately on to the bomber stream. Seventeen of the two hundred and eighty six attacking Lancasters were lost in spite of the introduction of the Mandrel Screen, MB Window and Jostle IV, although these RCM devices certainly caused difficulties for the German night fighter pilots.[7] The 8th Air Force too, was reminded just how well the Luftwaffe could still fight in defence of the Third Reich when, on 16 June 1944, considerable losses were inflicted on its bomber force during a daylight raid on Hamburg and central Germany. And again four days later, when forty-eight heavy US bombers were shot down out of a total of 1,361. On this latter raid, however, the Germans lost twenty-eight fighter aircraft.[8] As a consequence of the allies concentrating on oil targets, German fuel production fell from 927,000 tons in March to 472,000 in June 1944; a significant

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[6] PRO Air 20/1532, fitting of Oboe to forty Marauders of the 9th US Army Air Force and the failure of the equipment with the 8th USAAF.

[7] Adolf Galland, *The First and the Last*, p.314; Martin Middlebrook and Chris Everitt, *Bomber Command War Diaries*, p.527; Martin W. Bowman and Tom Cushing, *Confounding the Reich: The Operational History of 100 group (Bomber Support) RAF*, p.91

[8] Adolf Galland, *The First and the Last*, p.292.

reduction.[9] During the remainder of June, the small 803rd unit of the USAAF contributed some twenty-six sorties on five nights to 100 Group's Mandrel Screen. The idea of this vertical, moving wall of electronic jamming had grown out of the airborne Mandrel Centres, which had been used to good effect on D-Day. Now the plan was to produce such a screen, through which Main Force would normally fly, thereby delaying the Luftwaffe controller's decisions about the British choice of German target, until well after the bomber stream had penetrated the wall of jamming and emerged on the other side. At first the screen was flown at 15,000 feet until the night 27-28 June 1944, when it was raised to 19,000 feet. On this occasion, Main Force successfully attacked flying-bomb sites situated in the Low Countries and railway choke points with little loss, in spite of the fact that over a thousand aircraft were involved.[10] However, little penetration of defended airspace was involved.

2. No 80 Wing: Flying Bombs and Rockets

Within a week of 6 June 1944, V1 attacks had commenced against London (See Figure 19).[11] These pilotless aircraft involved were not radio-controlled, but a small number of them were fitted with M/F transmitters.[12] These enabled the Luftwaffe staff to plot the point of impact with the aid of ground D/F sites situated on the Continent. In view of this, No 80 Wing quickly developed a special organisation to Meacon these particular transmissions.[13] With the

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[9] Ibid., p.296.

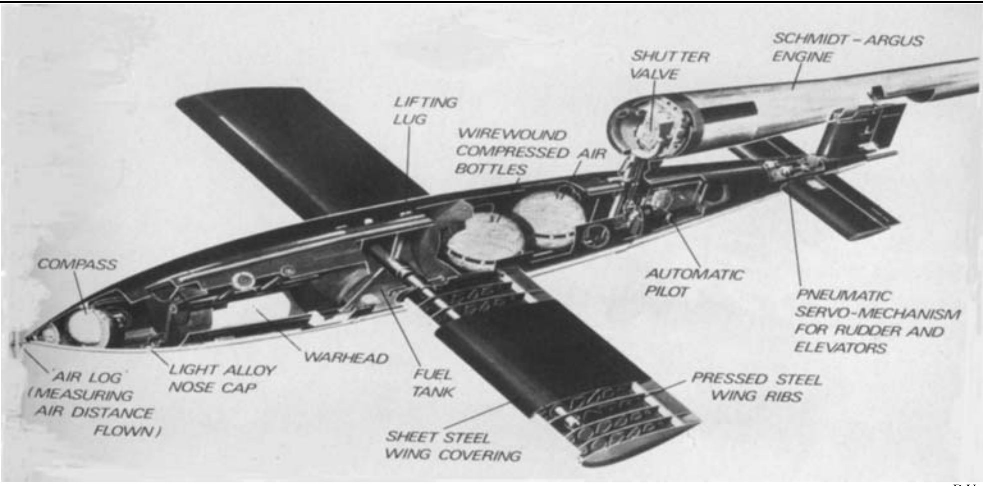
[10] Sir Arthur Harris, *Bomber Offensive*, pp.209-210.

[11] PRO Air 20/8777.

[12] A.I. 2(g) Report No 2244 dd.17 June 1944, quoted in PRO Air 41/46, p.65.

[13] PRO Air 41/46, p.65.

STATISTICS OF THE FLYING BOMB CAMPAIGN AGAINST THE UK



R.V. Jones

	Ground Launched (125-130 miles)	**Air Launched** (120-150 miles)	**Ground Launched** (190-200 miles)	**Total**
Period	13 Jun – 1 Sep 44	5 Sep – 14 Jan 45	3 Mar – 29 Mar 45	
Daily Av	102	8	6	
Max Eff 24 hrs	295	62	16	
Total Plotted	8081	1012	158	9251
No. Overland	5232	388	52	5672
Nos reached London	2340	66	13	2419
Nos destroyed by:				
AA	1564.5	320	86.5	1971
RAF	1902	72.5	4	1979
Balloons	278			278
RN	20	11	1.5	33
Total destroyed	3765	404	92	4261

The Blitz Then and Now

Figure 19

V1 Campaign against UK

commencement of this new German campaign, came a Directive from the Allied Expeditionary Air Force (AEAF) to attack V1 launching sites and supply depots in the Pas de Calais area of France, where the use of Oboe and G-H continued to reduce the probability of collateral damage and casualties amongst the French populace. Because of the threat to allied shipping, gathered off the invasion beaches, from German E-Boats an even higher priority was accorded by General Eisenhower to the destruction of German motorboat bases situated on the French coast[14]. One of the first of such raids was conducted against Le Havre on 14 June 1944, when one Lancaster was lost. The following day a similar attack was mounted against Boulogne. This pattern of events continued until the middle of September when control of Bomber Command reverted to the British authorities.[15] As a consequence of the threat to London posed by the flying bomb campaign, two of No 100 Group's Intruder Squadrons, Nos 85 and 157, both equipped with the very latest AI, the Mark X, then had to be diverted to RAF West Malling, in Kent, for anti-Diver or flying bomb patrols; carried out under the auspices of Air Defence of Great Britain (ADGB).[16] This move obviously had a deleterious effect on the fighter activities of No 100 Group and thus on the protection of main force aircraft.[17] Middlebrook and Everitt believed that they these two squadrons could easily be spared, but Air Chief Marshal Harris did not and backed the protest raised by the AOC of No 100 Group, AVM

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[14] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.521.

[15] PRO Air 14/1962, p.200.

[16] Martin Streetly, *Confound and Destroy*, pp.56-57.

[17] Ibid.

Addison.[18] The Air Ministry was unrelenting however, and No 100 Group lost the services of these two units temporarily. Fortunately for the allies, the attacks by the V1 flying bomb and V2 rocket commenced much later than the Germans had originally envisaged, due mainly to allied bombing of launching sites, supplies and research establishments.[19]

The delay was a crucial one for two reasons. Firstly, because, in order to create maximum effect, Hitler had hoped to have introduced both weapons simultaneously and in large numbers.[20] Secondly, the bombs and rockets actually arrived in the United Kingdom after the first landings in Normandy. Thus, in spite of the inherent inaccuracies of both weapons, if execution had matched intentions, then the numerous assemblies of allied armies and associated shipping, collected for the invasion and concentrated at ports along the south coast, may well have been selected as targets. If a deluge of such attacks had occurred at this juncture, critical Neptune timetables might well have been badly affected, thus placing the Normandy landings in jeopardy. Moreover, once ashore, the allied land forces inevitably became dependent on vast and regular supplies of all kinds and therefore, even at this comparatively late stage, the Germans could still have overcome the tardy arrival of the two Vengeance weapons. All Hitler would have to have done was to have directed ground and air-launched flying bombs and ground-launched rockets on to the critical lines of supply, which embraced the ports in the UK, used for embarkation and replenishment, the artificial harbours and the

[18] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.522; Henry Probert, *Bomber Harris*, p.296.

[19] David Irving, *The Rise and Fall of the Luftwaffe*, pp.161-162, 222-223, 268.

[20] David Irving, *The Mare's Nest*, (Panther Books), p.14.

beaches. The beaches at Arromanches, for example, were reputed to have handled 6,000 tons on a daily basis from July 1944 onwards, until such time as the first of the Continental ports could be captured and repaired. If this flow of material had been disrupted by these means then havoc and delay may well have ensued. But by then the V1 ground-launching sites, constructed previously in the Pas de Calais and the Cherbourg Peninsula, were mainly fixed in orientation. Nonetheless, some flying bombs were capable of being launched against ports such as Bristol and Southampton, as well as the London area. However, Hitler had been encouraged to believe, by carefully selected allied bombing patterns and various deception plans, such as Operation Fortitude, that the main thrust would occur in the Pas de Calais region.[21] After all, it contained two ports – believed to be essential for such a venture – and it was undeniably geographically nearer to the German border.

But if he still needed confirmation for these views, he reasoned that if he could swamp the British capital with the V Weapons based in France, then the Allies would be forced to capture the flying bomb sites as a first priority. Landing on the Pas de Calais coast and over-running the sites would have rid London rid of this particular threat at an early opportunity.[22] In the event, however, the first four flying bombs, out of a salvo of ten, did not fall on London and the south of England until nearly a week later in the night 12-13 June 1944.[23] The first of No 80 Wing's mobile units became operational on the Continent, near Bayeux from 19 June

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[21] Anthony Cave Brown Cave, *Bodyguard of Lies* (Harper and Row, Publishers, New York, 1975), pp.489-499.

[22] Albert Speer, *Inside the Third Reich*, p.481.

[23] PRO Air 41/46, p.65; Adolf Galland, *The First and the Last*, pp.309-310.

until 18 September 1944, but the only jamming undertaken was of random German R/T transmissions in the 38.2 to 42.5 Mcs band. With beam activity at a minimum, the second echelon, formed to protect Cherbourg, was re-equipped to include transmitters capable of Meaconing German M/F beacons. Due to the rapid advance inland by allied forces, this echelon was not sent to France. Moreover, because of the lack of interference by the Luftwaffe, some of the first mobile units were deployed to Wenduine in Belgium, for use against Big Ben, the V2 rocket, the remainder being returned to the United Kingdom. The Sonne-Elektra beam near Beauvais, however, had been active for considerable periods at night since 14 June 1944, though as a fixed Elektra. Since this beam could be used to aid attacks against allied targets in France, it was decided that stations in the south of England should take Meacon action, but the range proved to be too great for the jamming to be successful.[24]

The flying bombs, which were operated by the Luftwaffe, carried a warhead of about one ton and flew at a maximum speed of four hundred and forty mph, faster than most allied fighters. It was first used against Southeast England and, later, against allied positions on the Continent from 3 June 1944 to March 1945. Most of those directed against the United Kingdom were initiated from concrete ramps situated between Cherbourg and the Scheldt estuary. At the height of the campaign, in July and August, the daily number of bombs launched averaged around one hundred and occasionally two hundred. When the allied forces advanced into Holland, ground launchings against targets in the United Kingdom came to an end, but not those on the Continent. Instead,

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[24] PRO Air 41/46, p.64.

limited attacks were maintained by air launchings of the bombs, some fifty miles off the East Anglian coast. The Luftwaffe unit usually involved in these attacks was KG 53, and these continued until March 1945. The unit was equipped with He 111 aircraft based on some eight airfields in Northwest Germany. 1 KG 66 provided navigational assistance with the aid of Schwan Buoy.[25] Meaconing was begun against the radio emissions of the ground launched flying bombs, the aim being to produce false bearings in order to prevent the Germans obtaining accurate D/F fixes.

This was implemented by a special monitoring and control organisation of No 80 Wing, based at Ditchling, in Sussex, with an associated transmitter sited at Henfield.[26] By the time flying bombs came to be air-launched, they were no longer fitted with radio. Meaconing action was thus taken instead against the navigation beacons used by the aircraft navigators. The results of all this effort by No 80 Wing was difficult to assess, especially as the proportion of flying bombs fitted with radio was small. In spite of any Meaconing action, the Germans could have followed the early flight paths of the V1 with the aid of radar and estimated the time of flight from the amount of fuel carried or the cut-off point of the airborne transmitter. The RAF Y-Service reported that KG 53 probably made use of suitable low-powered beacons for this purpose. Indeed, so regular was this practice that it became possible to predict flying bomb attacks, with up to two or three hours notice, from the operation of the M/F aids.[27] Meaconing was thus employed as a countermeasure against these beacons and

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[25] Ibid.

[26] PRO Air 41/46, p.66.

[27] Ibid., pp.66-67.

when there was inadequate signal strength to drive the Meacons, use was made of Mimicry. This was a device, which had the effect of causing the Meacon transmitter to self-oscillate, thereby enabling the full power of the Meacon to be used, with a corresponding increase in range. On top of this and to prevent Mimics being used as beacons by German aircrew, the Meacons themselves were then Meaconed by conveniently situated 80 Wing transmitters.

The V2 rocket campaign conducted by the German Army, however, was a different matter altogether. The rocket was forty-six feet long and weighed more than thirteen metric tons, with a warhead of just under a ton. Hitler wanted to have nine hundred of these monsters produced monthly.[28] The campaign opened against both the United Kingdom and Continental targets in September 1944.[29] During its course, 1,115 rockets were targeted against England and 2,050 against the Continental targets.[30] In the previous July, HQ No 80 Wing had been ordered to prepare countermeasures against possible German rocket (Big Ben) operations.[31] It was thought at the time that the V2 rocket possessed a high initial trajectory and a maximum range of some two hundred miles.[32] Then parts of a trial rocket that had luckily been found in Sweden were smuggled into the United Kingdom, which, upon examination, revealed a number of complex transceivers, and radio receivers. It was thus assumed that these

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[28] Albert Speer, *Inside the Third Reich*, p.492.

[29] Adolf Galland, *The First and the Last*, p.310.

[30] PRO Air 8/1214; PRO Air 8/1215; PRO Air 8/1216.

[31] PRO Avia 7/2128; PRO Avia 7/2134; PRO Air 14/2894; PRO Air 14/2895.

[32] R.V. Jones, *Most Secret War*, p.453.

were associated with the control of the V2 and able to measure certain flight characteristics during trials. It was thought probable that the first ten miles of range or 45-70 seconds after launching was radio controlled.[33] (It subsequently transpired that the Swedish round was not a V2, but a Wasserfall anti-aircraft missile.)

From these somewhat mistaken assumptions it was proposed to apply countermeasures, when rocket signals were heard, or launchings reported from bases situated as far forward on the Continent as possible. These took the form of: jamming the 19-25 and 40-55 Mcs bands; application of a plain carrier or modulation with as much power as possible, FM or AM with tone or noise. The measures were to be directed towards any area within 200 miles of London, still available to the retreating German Army on the assumption that up to 20 signals could be active simultaneously. Three stages of implementing countermeasures were envisaged but, in the event, the rapid advance eastwards by the allied armies rendered the third unnecessary. An elaborate control organisation was instituted, based at Canterbury, with outstations at St. Margaret's Bay, Hope Point, Whitfield Tower and Crowborough. In addition Nos 214 and 223 Squadrons, of No 100 group, the latter unit being hurriedly formed with sixteen B24 Liberator aircraft on 23 August 1944, were to conduct airborne searches for V2 launchings and to apply appropriate countermeasures.[34] The aircraft concerned were specially fitted with search receivers and Big Ben, Jostle IV jammers, designed to operate in the suspected

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[33] David Irving, *The Mare's Nest*, p.28.

[34] PRO Air 20/1376, No 223 Squadron's Operational Record Book.

control frequency bands.[35] No 192 Squadron, with the help of information furnished by the RAF Y-Service, also conducted investigative flights in order to acquire additional intelligence.

Those patrols conducted in daylight, especially over The Hague, were often provided with an escort from the two Mosquito Squadrons based at Little Snoring. Alternatively, Spitfires from Fighter Command/ADGB were allocated to this particular task. Indeed, many of the group's other units allocated this role in daylight were also provided with suitable escorts (See Figure 20). The first rocket landed at Chiswick on 8 September 1944. Subsequently it was confirmed that some V2s contained two radios; a transceiver on 30 and 60 Mcs, re-transmission taking place on exactly double the received frequency and suggesting the use of velocity or ranging data by doppler, coupled with plain W/T signals, and a receiver working on 52 Mcs associated with a complex filter system installed for control purposes. Between 8 and 15 September 1944 some RCM transmissions were made when Big Ben warnings were received from RAF air patrols over The Hague, and from radar and Intelligence sources. Rockets landing in the United Kingdom followed a number of these sightings. The aim of the jamming signals was to interfere with the control of the fuel supply. But it is not known how successful this action proved to be. By the 15 September 1944, all ground-based RCM transmissions were halted in order to avoid interfering with the search for Big Ben signals; none were found. It was learned later that about the middle of October, the use of radio control was stopped in favour of the more effective integrating accelerometers; these were devices capable of measuring the rate of change of

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[35] PRO Avia 7/ 2212; PRO Avia 7/2213; PRO Avia 7/2214; PRO Avia 7/ 2215.

David Irving

Figure 20
V2 Rocket Sites

velocity.[36] Nevertheless, from the evidence available at the time it was deduced that the supposed V2 was indeed subject to some form of radio telemetry. Subsequently when the expected signal was received and jammed on at least two occasions, it transpired that the experts were not too far off the mark.[37]

Thus the UK Big Ben jamming organisation was disbanded. Arrangements, however, were made to send a contingent to the Continent when it appeared that the V2 campaign might be extended. In fact, rocket attacks continued until the spring of 1945 when the launching sites on the Continent, within range of the United Kingdom, were overrun by Allied ground troops.

3. The Rapidly Changing Strategic Situation

Meanwhile, the Allied Armies finally broke through the German defences in Normandy and, led by their armoured divisions, raced across France in all directions. A link was quickly made with the allied units, which had recently landed in Southern France. Paris was liberated on 24 August and Belgium was entered early in September, with the vital port of Antwerp being seized almost intact. In a few days most of that small country was completely liberated. The first American troops reached the German border near Aachen and Trier on 10 September 1944, where they met stubborn resistance in front of Germany's old frontier fortifications, the Siegfried Line. Holland was reached on 15 September.[38] Operation Market Garden, a major air landing operation, then occurred on 17 September 1944. Montgomery was

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[36] David Irving, *The Mare's Nest*, p.141 and footnote.

[37] PRO Air 41/46, pp.71-77

[38] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.565.

trying to advance over the rivers Maas, Waal and Lek into the north of Holland. In doing so, it was hoped to bring about the collapse of the German army in the west and thus hasten the end of the war. In spite of massive air support, however, in which No 199 Squadron and the 36th of No 100 Group contributed, Arnhem could not be held. The British army had landed in the middle of the 9th and 10th Panzer Divisions and the operation had to be regarded as a failure as early as 21 September 1944, the evacuation of the First Airborne Division taking place four days later.[39] As a consequence, most of Holland had to endure further months of German occupation. The breaking of the German armies in Normandy and the swift advance to the German frontier completely altered the war situation, raising hopes that the advancing troops could continue unchecked on into Germany, to meet the Russian troops advancing from the East and end the war in Europe before the winter. But logistics and the need to bring fresh manpower in from the United States intervened to prevent this happening. The allied commanders were seriously handicapped by lack of port facilities. It was true that Brest had fallen and was a useful port of direct entry from America, but it was now 500 miles from the new battle lines. The German army had left garrisons in all of the Channel ports and, although the allies held the port of Antwerp, the Germans still controlled the banks of its forty-mile river approach. The allied armies were thus forced to halt after Arnhem and wait for the clearance of the Channel ports and Antwerp.[40]

The question now arose as to how the strategic air forces were to be employed in future. Two schools of thought emerged: the first

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[39] F.H. Hinsley, *British Intelligence in the Second World War*, vol.3, pt. 2, pp.387-388.

[40] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.565.

in favour of attacking the Transportation targets, the second in favour of attacking the oil and petroleum industry. Oil won and a Directive to that effect was issued to Bomber Command and the US 8th Air Force on 25 September 1944.[41]

4. No 100 Group: RAF and USAAF Operations

In August 1944, the American authorities decided to merge the 803rd USAAF Squadron with the 856th, to become the 36th Bombardment Squadron (H) and move the new unit from RAF Oulton to Cheddington, a US Army Air Force base. Somewhat unusually, however, the 36th continued to form part of the RAF Mandrel Screen and fly by night. But this was only a temporary measure, for in October the 36th conducted its first sortie for the 8th Air Force forming a daylight Mandrel Screen, in order to protect United States aircraft.[42] Even so, support continued at night for the RAF. But this started to be phased out in November, when a Mandrel Screen was provided in daylight for US outward bound formations for the very first time. Some assistance, however, was still provided to the RAF in December, but during the first month of the New Year this co-operation virtually came to an end. It was not quite over, however, for in February 1945, the 857th and 858th Bombardment Squadrons (H) began bombing operations as part of the RAF's Special Window Force (SWF) and continued to do so during March and April 1945. The Special Window Force had become operational as early as 14-15 July 1944 and initially was made up from Nos 192, 199 and 214 Squadrons. Its purpose was to divert attention away from main force aircraft during operations by creating a false bomber stream or to provoke a reaction when

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[41] PRO Air 14/1962, p.200.

[42] Pat Carty, *Secret Squadrons of the Eighth* (Ian Allan Ltd, 1990), p.92.

main force was not operating.

Meanwhile, No 100 Group's three Serrate Squadrons were as busy as ever, although the number of actual contacts with German aircraft was diminishing fast, increasing interference from Luftwaffe RCM being experienced with AI Mk 1V. Nonetheless, the Group's fighter activities as a whole, Serrate and Intruder, certainly were worrying the Germans and upsetting their night fighter control procedures.[43] The two Intruder Squadrons, Nos 23 and 515 equipped with Mosquitoes were able to report greater success. The RAF Mandrel Screen was also extremely active, operating on sixteen different occasions during August as follows: six operations in support of main force over Germany, five operations in support of main force over France, when the screen was positioned over the Southern part of the North Sea to cover the Pas de Calais area and five Spoof raids. The Mandrel Screen was made up of aircraft from No 199 Squadron and the 803rd, augmented by six Mandrel fitted aircraft of No 214 Squadron. Moreover, in order to confuse the German Controller further, for the first time the Germans were permitted to 'see' the Special Window Force through an artificial break in the electronic wall. The Special Window Force operated on seven nights during the month, a response being obtained on three occasions. No 192 Squadron was also busy investigating German AI, the Egon air defence System and German signals generally in an area stretching from Calais to Sylt. Understandably, from the 4 August 1944, the unit was also charged with searching for transmissions associated with the V2.[44]

During the second part of the month monitoring continued of

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[43] Adolf Galland, *The First and the Last*, p.314.

[44] PRO Air 41/46, p.76.

Luftwaffe R/T transmissions and investigation of AI, and Wurzburg, Freya, Seetakt, Mammut ground radars and Egon. Moreover, a new German radar station was identified in the 30-49 Mcs band, situated on the Dutch coast, bearings being taken with the aid of a modified H2S set, Coalscuttle. No 192 Squadron was indeed proving to be a worthy successor to No 109 Squadron. August too, saw the welcome return of the two AI Mk X Squadrons to RAF Swannington from their Diver (V1, flying bomb) commitment with Air Defence of Great Britain.[45] At the end of the month No 5 Group conducted an attack against a distant target, Königsberg, situated beyond the 20-degree east line of longitude, which was an important German supply port for the Russian front. The raid achieved heavy damage around the four aiming-points selected; although fifteen Lancasters were lost out of a total of one-hundred-and-eighty-nine, due mainly to heavy fighter opposition over the target. The German Controller had rightly guessed the target, in spite of 35 RCM sorties and a host of diversionary tactics.[46] Obviously the RAF had still much to learn about how best to support an attack. During September, Bomber Command was employed on a variety of targets, many in support of the allied armies in their quest to liberate Europe and bring about a German surrender. Apart from Le Havre, a French port by-passed by the land forces, a heavy and successful raid was also executed against Darmstadt on the night 11/12 September 1944.

The German oil industry, however, was a priority target for both Bomber Command and the 8th Air Force. By the end of the month, only three plants out of ninety-one remained undamaged

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[45] Martin Streetly, *Confound and Destroy*, p.65.

[46] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.575.

and twenty-four only partly so.[47] In No 100 group, the Mandrel Force received a welcome and permanent reinforcement on the night of 15/16th when the newly formed No 171 Squadron carried out its first operation. Wing Commander M. Renaut commanded this unit, which was based at RAF North Creake where, initially it was equipped with Stirlings until the newer Mk 3 Halifaxes became available.[48] The Mandrel Screen was employed on 19 nights during the month, in support of Main Force operations, nine assisting minor operations and one spoof raid.[49] Throughout the month, No 214 Squadron was mainly employed on searching for V2 launchings, and operating Big Ben Jostle, but some HF/VHF Jostle sorties were flown in support of Main Force. To assist the unit, the new Jammer, Carpet 3, started to be fitted to selected aircraft. No 223 Squadron, later under the command of Wing Commander H.H. Burnell, became operational on 19 September 1944, with B24 Liberator aircraft, when it commenced Big Ben patrols by day and night in two offshore areas, adjacent to The Hague.[50]

During October, Main Force continued to attack oil targets such as Duisburg and Brunswick with some success, and managed to paralyse the synthetic petrol plants situated in the Ruhr.[51] Fuel and aircraft shortages were thus becoming a real problem for Germany and the defeat of the Luftwaffe an accomplished fact.[52] According to Albert Speer, however, for the

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[47] Adolf Galland, *The First and the Last*, p.313.

[48] Michael Renaut, *Terror by Night*, pp.146-147.

[49] Martin Streetly, *Confound and Destroy*, p.67.

[50] PRO Air 27/1376 p.3, No 223 Squadron's Operational Record Book, F.540.

[51] Adolf Galland, *First and the Last*, p.313.

[52] Richard Overy, *Why the Allies Won*, p.124.

moment there was no shortage of fighter aircraft, thanks to the Herculean efforts on the part of German aircraft industry.[53] RCM support to RAF Main Force aircraft was improving just as the Luftwaffe was losing that part of its Early Warning stations and raid reporting system based in territory overrun by the allied ground forces. In support of the land forces, Bomber Command attacked Walcheren in attempt to assist with the capture of the port of Antwerp, much needed for supply and replenishment purposes. During this period continued support to Main Force was provided by the Group's ever busy Mosquitoes and the Mandrel Screen, now made up from Nos 171, 199 and the 36th. The Special Window Force, formed when required from within the Group's own resources, was active on eleven occasions in October with aircraft drawn from Nos 171, 192. 199, 214 and 223 Squadrons, thus including aircraft from the Mandrel Screen for the very first time.[54]

Outstandingly successful was the Special Window Force (SWF) feint towards Bremen on the night of 7/8th, which was accompanied by high flying, and low level 100 Group Mosquitoes.[55] When Bremen was attacked in strength, one week later, fourteen aircraft were lost on this daylight raid, in spite of the presence of escorting fighters. The very same night No 5 group attacked the town of Brunswick, the raid being well supported by diversionary and other tactics. Another ploy introduced about this time, in order to confuse the German Controllers, was the attachment to the SWF of Oboe-equipped Mosquitoes of No 8 Group. These aircraft went through the full gamut of marking a target prior to a normal

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[53] Albert Speer, *Inside the Third Reich*, p.549 and footnote for controversial claim.

[54] Martin Streetly, *Confound and Destroy*, p.69.

[55] Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries*, p.597.

bombing attack, which of course did not materialise, but, it was hoped, added to the German's confusion. No 192 Squadron continued with its painstaking investigations into the Luftwaffe's radio and radar transmissions. Nos 214 and 223 Squadrons then used their HF and VHF Jostle IV on a number of sorties and discharged Window in support of Main Force operations. (For areas Windowed see Figure 21) During October and November, No 214 also had first use of the US equipment Dina, in order to jam SN2 radar. It was installed by TRE's Post Design Service, with the help of station personnel and later improved by TRE and given the name Piperack. It covered two frequency bands, 111-127 and 104-118 Mcs.[56]

Selected German towns and oil targets were then attacked in strength during November, notably Dusseldorf, Bochum and Gelsenkirchen. Oberhausen was attacked on the night 1-2 November 1944 but the target was covered with cloud and the bombing was scattered; perhaps because the Mandrel Screen was now being positioned to the east of Brussels, the Mosquito spoofs to Berlin and Cologne worked well and no aircraft were lost.[57] No 3 Group came to notice during this period when it carried out several daylight raids on oil targets using G-H, a blind bombing device that invariably proved to be remarkably accurate. Indeed, November was to prove to be the peak month of the Allied campaign against German oil production.[58] Although Bomber Command had reverted to national control in mid-September, support in daylight

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[56] PRO Air 25/777; PRO Avia 7/2304; PRO Avia 7/2636.

[57] PRO Air 24/298, Night Operations.

[58] Donald Caldwell, *JG 26*, p.305.

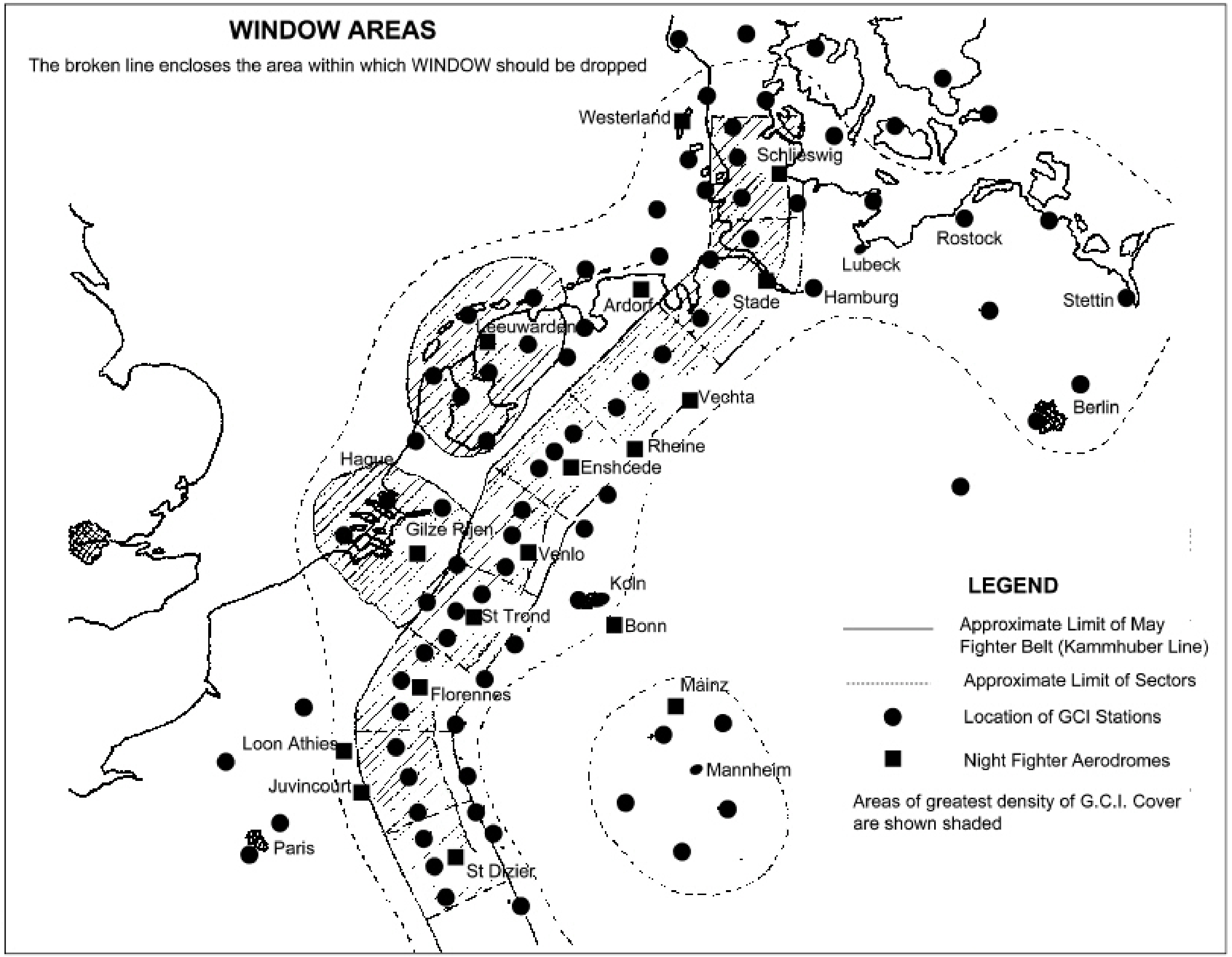

Figure 21

Window Areas

PRO Air 14/1962

was given to the American Army on 16 November 1944 by all main force Groups, except No 3 Group. The Mandrel screen was active on eighteen occasions during the month, with aircraft for the electronic wall generally being found from Nos 171 and 199 Squadrons, the 36th reverting to US national control on the 25th of November.[59]

In addition, ten raids were devoted to providing diversions during Main Force operations. Windowing was also initiated without any Main Force participation whatsoever.[60] Elint patrols were maintained by the indefatigable 192 Squadron, which managed to produce fifty-two sorties during the month, thirty-one by night and the remainder by day. Each of the seven fighter Squadrons of the Group operated on 12 nights and in addition completed a number of Day Rangers. Subsequent claims from the Mosquito Force for this period amounted to a total of 14 German aircraft destroyed. Because of the excessive secrecy surrounding No 100 Group's operations, these particular night operations were always fraught with additional danger to No 100 Group's own aircraft. Lewis Brandon of No 157 Squadron described how he nearly shot down a Liberator of No 223 Squadron on 29 October, simply because he had not been briefed to expect Liberators to be flying at night.[61] No 214 squadron flew one hundred and seven patrols with the SWF and a further twenty nine in support of Main Force using Window, Jostle, Carpet and Dina. (See Figure 21) No 223 Squadron completed 97 similar sorties. It should be noted, however, that due to shortages, the fitting of Piperack, into eight of

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[59] Martin Streetly, *Confound and Destroy*, p.73.

[60] Ibid.

[61] Lewis Brandon, *Night Flyer* (Crecy Publishing Limited, Manchester, 1999), p.185.

the B24 Liberators, using Dina equipment, was not completed until the twenty-first of the month.[62] At the end of November, No 100 Group celebrated the completion of twelve months' operations in support of Bomber Command; and station parties were held to mark the occasion during which air and ground crews celebrated with the only alcohol readily available, which was watered-down beer. December was the month in which Hitler decided to play his last card, and to launch his great ground offensive in the Ardennes with the object of capturing Brussels and Antwerp.[63] Powerful German forces were concentrated in great secrecy for the operation. Under appalling weather conditions, armoured and infantry columns made good progress in the Ardennes but the weather then improved, enabling the allied air forces to intervene for the first time. The German columns then started to suffer from a lack of fuel; the American Army refused to surrender at Bastogne and shortly Hitler's thrust to the west ground to a halt and eventually failed.[64] In the air the month was marked by a number of small, accurate raids by the RAF against targets situated in Germany, well supported by an increasing number of RCM operations.

Still there were exceptions to the pattern of small raids, such as Hagen. This town was attacked on the night of 2-3 December 1944 with five hundred and four aircraft drawn from 1, 4, 6, and 8 Groups, with the support of forty-four RCM sorties. Four aircraft were lost, or 0.6% of the force involved.[65] The oil plant at Leuna

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[62] PRO Air 27/1375; PRO Air 27/1376.

[63] Donald L. Caldwell, *JG 26*, p.311.

[64] PRO Air 25/783; PRO Air 27/1323; PRO Air 27/1375.

[65] PRO Air 24/303, Night Operations.

and the towns of Osnabruck, Essen, Ludwigshafen, Duisburg and Ulm were also hit hard by Main Force, all with few or no British casualties. Obviously, the loss of German Early Warning radar, together with the deterioration of the German night fighter force was beginning to have an effect. The raid on Cologne on the night 24-25 December 1944 was particularly effective, being helped by accurate Oboe marking.[66] In spite of bad weather and an extensive re-equipment programme, the Group Mosquito force had a good month, claiming the loss of some thirty-five German aircraft. The introduction of Clock patrols around Main Force targets in Germany, by Mosquitoes of No 100 Group, and additional bombing by similar aircraft with the aid of Gee contributed to this high score. The Mandrel Screen was in operation on eighteen nights involving some two hundred and nineteen sorties and Window was dropped on eighteen occasions by the Special Window Force now made up from 171, 192, 199, 214 and 223 Squadrons. Jostle was employed on two hundred and four sorties, along with Carpet, Dina and Piperack.[67] No 192 Squadron managed to complete one hundred and twenty eight Electronic Intelligence sorties before the end of the month and, on the 29th, RAF Foulsham received the last unit to join No 100 group. From Main Force came No 462 (Australian) Squadron from No 4 Group, complete with Halifax aircraft for Window and ABC duties. From the outset to maintain their morale the outspoken Australian crews insisted on carrying bombs as well as jamming equipment, as latterly did Nos 171 and 199 Squadrons.[68]

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[66] Ibid.

[67] Martin Streetly, *Confound and Destroy,* pp.96-98.

[68] PRO Air 27/1917.

5. 1945: Operations, Air and Ground

The New Year opened with a large-scale attack on allied airfields, by the Luftwaffe, in an attempt to destroy the Second Tactical Air Force on the ground in Holland, Belgium and France. There is some evidence to suggest that Unternehmen Bodenplatte had been planned to coincide with the Ardennes offensive, but that bad weather had intervened.[69] With difficulty, over eight hundred German aircraft and pilots had been assembled for Operation Hermann, which caused heavy damage. Over one hundred and forty aircraft of the Second Tactical Air Force were destroyed in the British area alone, and eighty-four damaged. But the Luftwaffe paid a price; around three hundred out of nine hundred of the attacking aircraft failed to return to their bases, together with their invaluable pilots.[70]

Even at this late stage, the aircraft could probably have been replaced, but not the experienced pilots and certainly not the flight and squadron commanders. The unsuccessful Ardennes Offensive eventually came to an end, but not until January 1945 and, with it, perished Hitler's last hopes for success in the west. This German thrust in strength had upset Eisenhower's timetable and consequently that broad obstacle, the Rhine, was not crossed in strength by the British Army until March 1945, when the final breakthrough into the German heartland commenced. For Bomber Command and the 8th Air Force the priorities remained the same, oil first and transportation second. Due to the weather, January 1945 was a quiet month. None the less, some attacks were carried

[69] Gebhard Aders, *History of the German Night fighter Force, 1917-1945*, p.207.

[70] Ibid.

out such as the successful breaching of the Mittelland Canal, on the night of 1 January 1945. Substantial support and radio Countermeasures were provided and the total loss for the night, including attacks on other targets, amounted to one aircraft out of five hundred and ninety eight sorties. Attacks then followed against Nuremberg, Ludwigshafen, Dortmund and Castrop-Rauxel, with similar support and low loss rates among the participating aircrews. The results of the two raids conducted on the night 5-6 January 1945, however, were different. Hannover was attacked with 664 aircraft, with a loss of 31, or 4.7per cent, and Houffalize, a bottleneck in the German army supply system, was bombed with great accuracy by 140 aircraft, with the loss of only two Lancasters.[71] Supporting both raids were 69 Mosquitoes which were sent to Berlin, 8 to Neuss and 6 to Castrop-Rauxel, plus some 58 RCM sorties, which included Window and Jostle support, and a further 55 five Mosquito patrols, with the result that 4 Mosquitoes were lost, two from the Berlin raid and two from 100 Group.[72] On this occasion it is perhaps of interest to note that the navigation of No 100 Group Window Force was sufficiently inaccurate for it to be commented upon. In order to obtain the optimum results Window had to be dispensed not only in the designated area at the right time, but also at the required rate; and thus any discrepancy was severely frowned on.[73] The total loss for the night amounted to 37 aircraft or 3.7 per cent. Munich was attacked twice on the night 7-8 January 1945, when 11 aircraft were lost in spite of Window and Jostle support; obviously the German night defences were not yet

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[71] PRO Air 24/304, Int. 3 HQBC; PRO Air 24/306, Int. 3 HQBC.

[72] PRO Air 24/304.

[73] PRO Air 14/2894; PRO Air 24/304, Interceptions/Tactics Report No 7/45.

quite extinct.[74] Generally, however, for the remainder of the month the aircrew casualties remained low. The Special Window Force of No 100 group was active on eleven nights, generating some 238 sorties, the entire Group's heavy aircraft being involved with Nos 171, 192 and 462 Squadrons dropping bombs after completion of their Mandrel or Window commitments.[75] Indeed, No 462 Squadron inaugurated this new departure on 7 January 1945.

One week later No 223 Squadron lost their first aircraft providing support to Main Force which was attacking the synthetic oil plant at Leuna, the rail yards at Grevenbroich and the Luftwaffe fuel storage depot at Dulmen.[76] A similar pattern of events occurred in February, up until the 13-14th of the month, when the controversial raid on Dresden, a vital supply and communications centre for the Eastern front, occurred, together with an attack on the synthetic oil plant at Bohlen.[77] The bombs on Dresden raised a firestorm similar to, but greater, than the one at Hamburg and heavy German casualties ensued. Nine aircraft were lost, or 0.6% of the total of 1,406 sorties. The raids were heavily supported by seventy one Mosquitoes to Magdeburg, sixteen to Bonn, eight each to Misburg and Nuremberg and six to Dortmund; and from No 100 group, came sixty five RCM sorties and fifty nine Mosquito patrols.[78] During the month the SWF produced two hundred and thirty eight sorties, three of the participating squadrons going on to drop bombs. No 223 lost its second aircraft on the night 20-21,

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[74] PRO Air 24/304.

[75] PRO Air 27/1102; PRO Air 27/1156; PRO Air 27/1917.

[76] PRO Air 24/304; PRO Air 24/306.

[77] Henry Probert, *Bomber Harris: His Life and Times*, pp.316-321.

[78] PRO Air 14/2894; PRO Air 24/308.

supporting Main Force attacks in the Dortmund and Dusseldorf areas, when again HQ No 100 Group commented upon the accuracy of the navigation of its Window Force.[79] Ironically, on the night 24-25 when Main Force was not operating, five aircraft were lost from the Group participating in a Spoof raid, together with four Halifaxes from No 462 Squadron and one B17 Fortress from No 214 Squadron.

Moreover, in spite of the Luftwaffe's desperate situation, some two hundred Luftwaffe aircraft implemented Operation Gisela and attacked targets situated in the United Kingdom on the night 3-4th March 1945. The German aircraft succeeded in integrating into the RAF bombers returning from Kamen and the Dortmund-Ems Canal, destroying twenty RAF aircraft, including a B17 of No 214 Squadron, which was brought down over its home base, RAF Oulton. This was not the total number for the night, however; these losses, when added to those aircraft lost on operations against Kamen and the Dortmund-Ems Canal, amounted to twenty eight aircraft or 3.6%, in spite of some sixty-one RCM sorties and a host of other diversionary sweeps and operations.[80] Further losses were incurred two nights later when, thirty-one aircraft were lost as a result of an attack on Chemnitz and the synthetic oil refinery at Bohlen, even though fifty-two RCM sorties were flown. The Special Window Force was active on twenty occasions during March and dropped two hundred tons of Window and three hundred and twenty tons of bombs. To help improve the accuracy of navigation, HQ No 100 Group then introduced, rather late in the proceedings, a system of broadcasting meteorological forecasts, including wind

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[79] Ibid.

[80] Simon W. Parry, *Intruders Over Britain*, pp.126-135; PRO Air 14/2894, 100 Group Nav. Plots.

velocities, to its aircraft at regular intervals. This pattern of events was maintained almost up to the end of hostilities, many of the sorties being completed without any losses at all.

There were still, however, a number of exceptions as was the case on 7-8 March 1945 when Dessau, the refinery at Hemmingstedt, and the oil refinery at Harburg were attacked. Diversions and Support measures, as usual at this stage of the war, were extensive. Out of 1276 sorties, forty-one aircraft were lost or 3.2% of the force. At the end of the month the Blohm and Voss shipyards at Hamburg were attacked with four-hundred and sixty-nine aircraft. Eight Lancasters and three Halifaxes were lost, a number of the aircraft falling to the unexpected intervention by the Luftwaffe's day-fighter force. This figure, however, was surpassed four nights later when three oil plants and refineries were attacked, resulting in the loss of sixteen aircraft. This was all the more galling, because on this occasion, No 100 group produced one hundred and thirty-six aircraft in support of Main Force, its largest effort of the war. By now the Mandrel Screen had been dispensed with; such protection being provided by the aircraft concerned flying in the stream itself. The Special Window Force thus became part of the Main Force.[81] The last sorties of the war against Germany by Bomber Command took place against Kiel, where it was feared that German troops were being sent to Norway in order to continue the war. Sixteen Mosquito Bombers of No 8 Group, the Pathfinders and thirty-seven of No 100 Group were involved; one Mosquito of No 169 Squadron was lost during a low-level napalm attack against Jagel airfield. One hundred and twenty six Mosquitoes of No 8 Group then attacked Kiel; eighty-nine RCM

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[81] PRO Air 14/2911.

aircraft had been sent to support the Mosquitoes when two Halifaxes, from 199 Squadron of the Mandrel Screen, collided during a bombing run over Meimersdorf. It thus came about that the last casualties to be sustained by Bomber Command during operations over Germany came from the Command's last operational Group to be formed – No 100 Group.

Summary

There is little doubt that the employment of the numerically large strategic bomber forces in a tactical role before, during and after D-Day, under the direction of SHAEF, was a wise, if not always a popular decision with officers like Sir Arthur Harris; it reaped great dividends. The strategic air forces helped to soften up German defences and thus contributed to a reduction in the numbers of casualties among the allied armies. Moreover, there was often capacity to spare so that strategic targets, such as oil refineries, could also be attacked. Because RAF Bomber Command, however, was a somewhat imprecise weapon, collateral damage and casualties to the civil population were often important considerations when targets situated in the occupied countries were being selected. For this reason, maximum advantage was taken of the accuracy associated with the blind bombing aids, Oboe and G-H. So large were the British and American bomber forces that they easily outnumbered the depleted German fighter force. But German industry was well organised and generally capable of replacing most losses of fighter aircraft remarkably quickly. Oil refineries were repaired too, after an attack, a task made easier when the bomber forces were required to return to the tactical role, which they frequently were at the time. As a consequence German fuel stocks fluctuated wildly. In spite of numerical inferiority the German fighter force, night and day, remained aggressive and in June the loss rate to Bomber Command exceeded 6 per cent.

New techniques and devices such as the moving Mandrel Screen, an innovation stemming from the D-Day Mandrel Centres, and Jostle IV along with MB Window had either just been introduced or were about to be, and the loss rate started to decline. Moreover, the 803rd USAAF Squadron was now participating in the RAF Mandrel Screen, affording a timely opportunity for the 8th Air Force to learn about, and gain experience of, airborne radio countermeasures. Undoubtedly, the allied bombers suffered losses during these operations and bombing raids, sometimes quite grievously, but so did the Luftwaffe. Each time a German fighter pilot was lost he had to be replaced, invariably with someone of less experience; and even this process was becoming difficult. A week after D-Day came the V1 attacks upon which Hitler had set great store. The flying bomb campaign, however, was too late to have much effect on Neptune and Overlord, the bombs being primarily directed towards London and the Southeast. Since some were fitted with radio transmitters, No 80 Wing started to Meacon the radio transmissions. But just how effective these efforts were, were difficult to judge, as the bombs could be followed by Luftwaffe radar and, ranges estimated with the aid of fuel calculations. The V2 rocket was a different matter altogether, although from the German point of view, like the V1, it arrived on the scene late and in insufficient numbers. Early missiles carried complex radios and Big Ben Jostle IV was employed to jam any control instructions being passed. However, there was no way of stopping the rockets: the people of London and the Southeast had to endure the campaign until allied ground forces overran the launching pads situated on the Continent, within a two hundred mile radius of the United Kingdom.

The break-through was not too long in coming. Allied Armies liberated Paris in August and entered Belgium and Holland the following month. This impetus was lost at Arnhem when the British Army was brought to a halt, thus ensuring that the war would continue at least into the New Year 1945. Oil now became the number one priority, over Transport, for Bomber Command and the US Army Air Forces. Meanwhile, the 803rd Squadron became the 36th but continued to operate with No 100 group, while experimenting, and gaining experience, with various forms of Mandrel Screens for the 8th Air Force. No 100 Group Serrate-equipped Mosquitoes, however, were becoming less and less successful as the new Luftwaffe AI, SN2, started to be installed. Fortunately, the Group Mosquitoes employed in the Intruder role were now meeting with much more success. No 100 Group's Mandrel Screen was very active in August and for the first time its Squadrons started to participate in the Special Window Force. Throughout No 192 Squadron continued with its quest of searching for electronic intelligence. The following month, August, Bomber Command supported the Allied ground forces but also attacked the German oil industry; these attacks together with the daylight assaults delivered by the US, were to lead eventually to a German oil crisis. No 100 Group was strengthened by the addition of Nos 171 and 223 Squadrons, the latter joining No 214 patrolling the area of The Hague, looking for and reporting launchings of the V2 rocket. In mid-month Bomber Command was released from its commitment to SHAEF and returned to national control. By October the Germans were indeed suffering from a shortage of fuel which had to be carefully husbanded.

RCM support provided by No 100 Group for Main Force was greatly improved and loss-rates were brought down to an acceptable 1% level, this position being greatly helped by the Luftwaffe losing much of its early warning through the occupation of much of France, Belgium and Holland by the advancing Allied armies. The Special Window Force was particularly active, with Mandrel Screen aircraft participating on a regular basis and helping to swell the amount of Window being delivered against the German radar controlled defences. October also saw the end of the Big Ben patrols conducted by Nos 214 and 223 Squadrons and the fitting of the new Dina/Piperack jammers into the aircraft of these units for use against the Luftwaffe AI, SN2. Selected German towns and oil installations continued to be attacked in November by Bomber Command, indeed it was to prove the peak month when Bomber Command and the 8th Air Force both went after oil production, synthetic oil installations and oil storage depots; No 3 Group was even authorised to try daylight bombing of these priority targets, making full use of the accurate blind bombing device, G-H. In December, Hitler launched his last big gamble with the offensive in the Ardennes. Under favourable weather conditions, strong German ground forces struck west hoping to drive a wedge between the American and British armies and capture Brussels and the important supply port of Antwerp. However, when the weather cleared, enabling the full weight of allied air power to be brought to bear, the attack started to peter out, hastened by a shortage of oil. Meanwhile oil continued to be the priority target for the heavy bombers and the deterioration of the German night fighter force became more noticeable.

Support to Main Force by No 100 Group was also improving; not only were the Mosquitoes having more success, brought about by their improved radar equipment, but the Group's heavy units were augmented by the addition of No 462, Halifax, Squadron. Even the Special Window Force could field five four-engined aircraft Squadrons, namely: Nos 171, 192, 199, 214 and 223. New Year's Day, 1945 opened with a devastating and surprise German air attack on 2 TAF airfields by nine hundred German fighters, much damage being done to RAF aircraft and equipment. More serious, though, were the losses to the Luftwaffe in experienced pilots and the three hundred aircraft. During January the Ardennes offensive came to an end, enabling Eisenhower to resume his ground thrusts towards the East, and in March the final break-through commenced towards the German heartland. In the closing months of the war substantial support was available to Main Force from No 100 group, and, as one would expect, the loss-rate continued to remain at a low figure. There were still some surprises, however, and the Luftwaffe mounted one last, and successful, attack against the United Kingdom in March, Operation Gisela; when the RAF lost a substantial number of four engined aircraft. Outnumbered, short of fuel, pilots and aircraft, the Luftwaffe nonetheless continued to fight, right to the end of hostilities. In order to compare the size of No 100 Group, with those of the other major formations of Bomber Command at the time, the Order of Battle for March 1945 is given below:

HQ Bomber Command Order of Battle, March 1945

HQ No 1 Group – 14 Squadrons Lancasters

HQ No 3 Group – 9 ½ Squadrons Lancasters

HQ No 4 group – 11 Squadrons Halifaxes

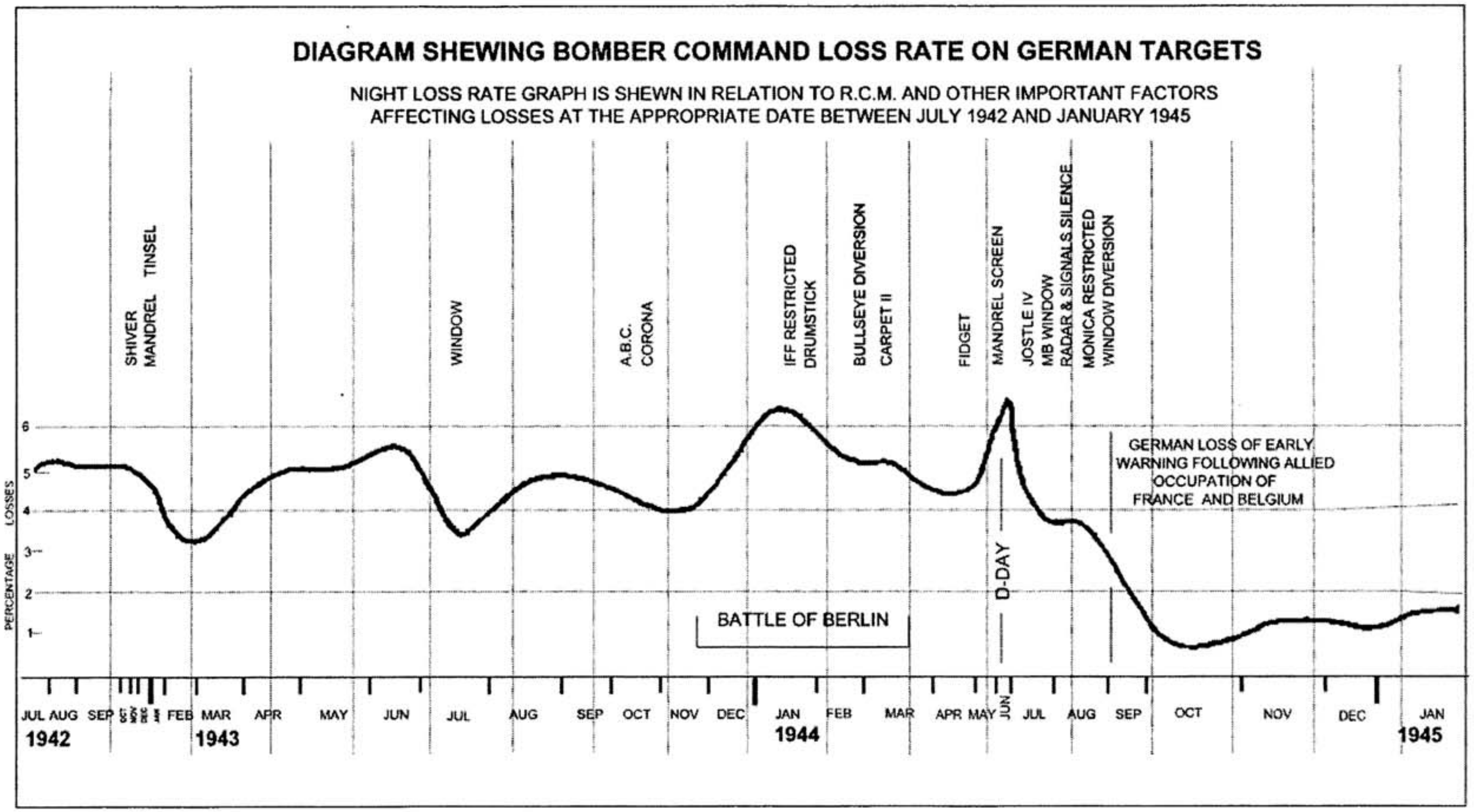
HQ No 5 Group – 15 Squadrons Lancasters,
3 Squadrons PFF Lancasters and Mosquitoes

HQ No 6 (RCAF) Group – 13 Squadrons Lancasters and Halifaxes

HQ No 8 (PFF) Group – 19 Squadrons Lancasters and Mosquitoes

HQ No 100 Group – 13 Squadrons Mosquitoes, Halifaxes, Fortresses and Liberators.[82]

[82] C. Webster and N. Frankland, *The Strategic Air Offensive against Germany, 1939-1945*, vol.4, pp.419-420.



SIGS1 HQBC

Figure 22
Bomber Command Loss Rate

CONCLUSION

When the Prime Minister, Neville Chamberlain, declared war on Germany on 3 September 1939, the three British services were not really in any fit state to go to war. Disarmament had started shortly after the end of the First World War and had continued until well after Hitler had become Chancellor of Germany in 1933. Although by 1935 rearmament had begun, the services were finding it difficult to expand quickly, with a reduced domestic armaments industry and an even smaller aircraft industry. Fortunately for the British, Watson Watt had developed radar in the United Kingdom and an integrated air defence system had been instituted with Fighter Command at its heart. But in May 1940, the British Expeditionary Force had been expelled from the Continent by the Germans, and forced to abandon most of its equipment either in the hinterland of France or on the beaches; at the same time Bomber Command was incapable of taking the war to the German heartland. There is little doubt that, in fighting the great daylight battles of 1940 from July until October 1940 successfully, Fighter Command saved the United Kingdom from invasion and presented it with an opportunity to continue to prosecute the war. A new Prime Minister then ensured that Bomber Command would be given the national resources with which to strike hard and sure against the German homeland.

It has been demonstrated that radar had also been invented in Germany, unknown to the British. The Luftwaffe had also developed navigation and bombing techniques by radio, making it in this respect the most advanced in the air force world. The presence of the Luftwaffe navigation and bombing beam, Knickebein, was confirmed over the United Kingdom, on the night 21-22 June 1940, transmitting on a frequency of 31.5 Mcs, by an Avro Anson aircraft of WIDU, the Wireless Investigation and

Development Unit, captained by Flight Lieutenant H.E. Bufton. The discovery came as a revelation to the RAF and the government. The United Kingdom simply had nothing to compare with Knickebein, or the Ruffians and Benito beams. Night flying and instrument flying were not strong suits in the RAF at the time, although this state of affairs was rectified in due course.

The Luftwaffe also made extensive use of medium frequency radio beacons for navigation purposes and, in July 1940, the British decided to erect a number of re-radiating transmitters or Meacons; the BBC and GPO Research Establishments helping to evolve a method of picking-up the German signals, and using them to drive the RAF transmitters. The first Meacon station became operational at Flimwell, Tonbridge Wells, on 24 July 1940. Almost immediately HQ Fighter Command was given control of radio countermeasures, during the first phase of the Battle of Britain: the decision was not well-timed and realising that a separate and expanding organisation was likely to be required, No 80 (Signals) Wing was formed for the purpose in August 1940, under the command of Group Captain E.B. Addison, and placed under the direct control of the Air Ministry. It did not form part of Bomber Command until December 1943. Thus, the first aim of this thesis to explicate the search for and finding of, these beacons and beams has been met.

By August 1940, the second of the beams, X-Verfahren, were heard on the Kent coast being used by KGr 100 in the 65-75 mcs frequency band. This unit was present at the attack on Birmingham, as early as 13-14 August 1940 and again on 26-27 October 1940. Enigma disclosed the existence of the third Luftwaffe beam in October 1940, the advanced Y-Verfahren or Benito, operating between 40-50 mcs. The three Luftwaffe navigation and bombing beams had been found and identified. This thesis has argued that the Luftwaffe's three beams were of advanced design and that their use over the United Kingdom caused the Royal Air Force surprise and concern. By way of response a suitable formation was quickly organised and put in place. It has been demonstrated that action was taken by the Air Ministry from June 1940, onwards, to reduce and nullify the Luftwaffe use of the Medium Frequency beacons and the Knickebein, X-Verfahren and Y-Verfahren beams as they were identified. The authorities had little specialised equipment to start with, apart from the Meacons, and it had to experiment with hospital diathermy sets against Knickebein. By April 1941, No 80 (Signals) Wing possessed sixteen Meacon, twenty-eight Aspirin, seventeen Bromide and six Domino sites and stations, linked by a communications system to a viable operational headquarters. With this extensive inventory of radio equipment this thesis has argued that the RAF managed to contain and then win the defensive radio war, thus saving British industry, especially those factories producing aircraft, from almost certain destruction. Thus, the second aim of the thesis, to examine the reasons why No 80 (Signals) Wing was created, to investigate its organisation and operations, and to confirm how it was controlled, has been met.

In order for No 80 Wing to carry out its task successfully, it was important that a timely and constant flow of intelligence about German call signs and frequencies was received. Fortunately for the British, Enigma at Bletchley Park was able to furnish much of this information, together with the Y-Listening Service, RAF stations Cheadle, and Kingsdown, and No 109 Squadron. The Meacon system was outstandingly successful and, in the hands of No 80 Wing, resulted in a number of Luftwaffe aircrews becoming lost and subsequently landing their aircraft in the United Kingdom. Subsequent interrogation of the crews and examination of the German aircraft, chiefly by RAE Farnborough, yielded much-needed information to British Intelligence, and the countermeasure organisation. Beam jamming was not always as effective as the Meacons; when the weather was good during a German attack on the United Kingdom, conflagrations on the ground could often guide other German aircraft to the target, irrespective of the efficiency of the jamming.

It took until early 1941 for TRE to produce Domino, the first of the purpose-designed jammers employed against this device. It was, however, to be some time before all the complex details of the system were unravelled. When this was done, TRE decided to discard Domino in favour of Benjamin, which jammed the associated R/T channels. It has been demonstrated in this thesis that No 80 (Signals) Wing was not always successful, mistakes were made as at Coventry. But by perseverance and persistence this formation, with help from the Air Ministry, and assistance from the research establishments, developed into a formidable countermeasure organisation, complete with an extensive network of Watcher and Jammer sites. By May 1941, the battle of beams had been won; the RAF countermeasure organisation had defeated the Luftwaffe's beacons and beams. Thus the third aim of the thesis, to trace the early and subsequent ground-based measures taken to nullify the Luftwaffe's beacons and beams has been achieved.

The Wehrmacht attacked Russia on 22 June 1941 and in consequence much of the Luftwaffe was withdrawn from the west, but not all of it. Sufficient strength was retained to keep Fighter Command fully stretched. In 1942 the Channel Dash occurred and because of the jamming, for the very first time, of British radars during the transit, Bomber Command's attitude changed towards the protection to be gained from the use of radio countermeasures. By the end of 1942, it had become obvious that the myriad of ground and airborne jammers now available, some operated by Fighter Command on behalf of Bomber Command, would require a high degree of co-ordination and control which only a separate formation could provide. Thus No 100 (Bomber Support) Group was formed in December 1943 and placed in Bomber Command. Raising a new Group during hostilities was a challenge, especially one requiring new types of equipment and techniques; moreover, other units were reluctant to release their personnel and aircraft. Hence No 100 group took time to evolve and mature: flying units had to be acquired and airfields found on which to base them, and crews had to be converted to their new role, when shortages of equipment often delayed the process. Nonetheless, the formation did provide much-needed support to Bomber Command and, in doing so, helped to contain and reduce its loss rate. No 100 Group made a significant contribution to the D-Day proceedings and afterwards went on to continue to support Bomber Command for the remainder of the war: this invariably involved the provision of a Mandrel Screen, Window protection for the main stream en route to, and over the target, and employment of the airborne jammers Jostle IV, Carpet, and Piperack; and in order to confuse the German Controllers and delay recognition of the intended target for as long as possible, diversions and feints were developed and improved to a high degree. In so doing No 100 group made a vital contribution to the offensive phase, ensuring its success. The reasons why and how No 100 (Bomber Support) Group came to be formed and its organisation have been investigated; moreover, its success and failures have been described, thus meeting the terms of the fourth aim of this thesis.

No 80 Wing had to rely on the British Research Establishments, principally the Telecommunications Research Establishment (TRE) at Swanage, and later Malvern, for an initial supply of specialist jamming equipment and transmitters. TRE was capable of producing prototypes of the equipment it designed, but not of mass production. For large numbers of devices, the authorities had to turn to the small, hard-pressed domestic radio industry. When this approach was unsuccessful, the United States contributed to much of the shortfall, under arrangements initiated by Sir Henry Tizard during his visionary and significant visit to the USA and Canada in September 1940. But TRE was more than a Research Centre, it was also a think-tank which produced a series of original papers on how new items could best be employed. Moreover, its Sunday Soviets became an invaluable mechanism whereby problems arising out of the use of new equipment could be discussed at the highest level and overcome. After the war, many of TRE's developments led to improvements in the civil aviation field, especially in flight safety and in forward-looking radar; and on the domestic front, the evolution of the microwave. The telecommunications establishment, and its antecedents, came into being because of the dire necessity for a British radar chain to be in position before the outbreak of World War Two. This work absorbed almost all of the establishment’s capacity. After this task was accomplished, TRE was able to give more attention, in the autumn of 1940, and in the first half of 1941, to the development of airborne radar and helping to reduce the effects of the Luftwaffe's night bombing of the United Kingdom. Fortunately for the British, TRE had formed a radio countermeasure group in August 1940, under the supervision of Dr. Robert Cockburn. The RAF relied very heavily on this group and especially with the establishment’s plans for D-Day. The contribution made by TRE to the radio war fought by the Royal Air Force has been thoroughly examined, so meeting the fifth aim of this thesis.

Since the Bomber Command paper on the advantages to be gained by the use of radio countermeasures was published in August 1942, and the meeting to consider the adoption of RCM, was held at RAF High Wycombe in the following October, it raises the question whether or not No 100 Group could have been established earlier than December 1943, with all the attendant advantages that such a step could have brought? The answer is 'Yes'. Development of airborne countermeasures was already in progress; moreover Bomber Command was in favour of such a decision along with others, such as TRE. But the Air Ministry judged that the United Kingdom was still too vulnerable to air attack to initiate a jamming war, and thus withheld general permission to use such devices. Had the new Group been formed in December 1942, rather than a year later, impetus would have been given at an earlier date to the research and design of countermeasures. This in turn would have led to a timely formulation of jamming policies and techniques, thus expediting the production of airborne equipment and its use, and hastening the reduction in casualty rates.

Success in the Normandy landings on the 6 June 1944 was largely attributable to the massive air superiority enjoyed by the Allies. Since it was impossible to guarantee that all the German radar stations in the invasion area were rendered unusable before the assault took place, recourse was made to radio countermeasures. These were highly successful on the day and by blinding this particular source of German early warning, doubts were raised in the mind of the German High Command as to whether this was the main and only landing. Consequently, vital decisions about committing reserves and reinforcements were delayed.

The radio war was won against Germany, but not by any one individual or formation; it was a concerted effort. No 80 Wing would have been impotent without a constant flow of information from the Y-Service, especially RAF Cheadle and RAF Kingsdown, and Enigma; and a stream of new or improved equipment coming from TRE. No 100 Group was dependent on the details about the German night fighter defences, provided by No 192 Squadron and Bomber Command; at the Air Ministry, Dr R.V. Jones of Scientific Intelligence, watched over the entire campaign thus helping to ensure a successful outcome of the radio war fought against Germany from 1940-1945.

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