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

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CHAPTER 6
PLANNING OF OPERATIONS

Introduction

A knowledge of weapon effectiveness and of bombing efficiency and accuracy within the Bomber Command have many applications in furthering the effectiveness of operations but one of its most important applications lies in assessing the weapon and force requirements for a given task. Such an assessment can prevent either the waste of effort and bombs through overhitting or attempts to neutralise a target with an inadequate force, a matter which becomes very important when the time factor is of prime interest. It is essential also in appreciating a strategic or tactical plan of bombardment requiring the neutralization of a set of targets in a given time in order to assess whether the task is within the powers of the force available.

Assessments of this nature require an acquaintance with the laws of probability as well as in intimate knowledge of bomb performance and bombing efficiency, and, in the case where a series of targets are involved the assessor must be aware not only of the influence of such things as weather conditions in bombing efficiency but also the frequency with which various sets of such conditions are likely to occur. For these reasons it was natural that the responsibility for planning calculations of this nature should fall upon the O.R.S. Nor was their work in this field confined to the requirements of the Command for from time to time they were called upon to advise the Air Ministry in those matters.

Planning of Operations, 1942 to 1943.

Until the end of 1943 the question had arisen only infrequently because at that time the Command seldom attacked targets other than German or Italian towns and the strength and efficiency of the Command at that time rendered it unlikely that such targets would be overhit even when the whole force was used. From time to time however such problems did arise. It is impossible to chronicle all of them because they eventually became too numerous and, particularly in the early days, they were of such a confidential nature that records were seldom kept in the usual way.

As far as can be recalled the first estimate of this nature was made in August 1942 when the target postulated consisted of a row of pylons at a radio station. The operation was not, in fact, carried out. Early in 1943 came the first discussion in calculating weapon and force requirements when the possibility of using the heavy bomber force in support of land and sea operations was first mooted. This was in connection with Operation Constellation which involved a sea-borne landing on one of the Channel Islands (Alderney) as a diversion to similar operations in the Mediterranean.

The task of the heavy bombers was to neutralize coastal defence guns and beach defences such as machine gun posts, wire, minefields and anti-tank obstacles. The problem was to choose the most effective bombs,

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decide what densities were required in the various areas of the target, and work out the force required and the best disposal of aiming point to achieve these densities. The purpose was not only to assist in the planning of such an operation but even more to assess whether the task was within the capabilities of the bomber forces available. During the same period proposals discussed at Air Ministry regarding possible new directives gave rise to appraisals of the railway system in enemy and enemy-occupied territories and of synthetic oil plants in the Ruhr.(1)

The method used in all these problems was basically the same throughout. The layout of the target complex and the construction of the sub-targets was examined as carefully as available data would allow. Experimental data or the results of operational analysis on the effect of bombs were then studied so that a radius of effectiveness or mean area of effectiveness could be postulated if not already directly available for the range of bombs likely to be useful. Where necessary the advice of relevant experts, such as those in the Research and Experiments Department (R.E.8) of the Ministry of Home Security, was sought. From these figures the best type of bomb-load and the number of hits on the target or the density required over the target area could be derived. Such information as existed on the efficiency of the Command was then manipulated so as to give the number of aircraft which must be dispatched to give a prescribed chance of achieving this density. This would of course take into account such things as weather, range of target and the nature of the defences likely to be encountered. If a series of attacks were involved it could then be stated how many sorties in all were required to produce a given expectation of successful attacks.

The statistical methods involved were straightforward; sometimes ad hoc calculations were made, sometimes probability grids were used. In the earlier days however, difficulty arose in the scarcity of quantitative information both on the weapon effectiveness and the bombing efficiency aspects, and it was necessary to make bold estimates of the parameters involved. As time went on, however, this difficulty was gradually resolved and the estimate became more and more reliable. This was fortunate for at the same time the necessity for such estimates and their importance increased as the possibility of the use of heavy bombers in the tactical scheme became more real.

A second plan similar to Operation Constellation but this time based upon targets on the coast of France between Boulogne and Calais (Operation Starkey) was studied and then, in September 1943, the whole subject of fire support for an opposed landing was reviewed by an Inter-Service Committee. O.R.S. Bomber Command was called in to make an appraisal of the part which could be played by heavy bombers and the force likely to be required and this was included in the Committee's report.(2)

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(1) See A.H.B. Narr. 'The Liberation of North-west Europe', Vol.I. Chap.
(2) A.H.B./IIS/136.

Planning of Operations in 1944

The railway system question arose again in January 1944 and became urgent a few weeks later when a proposal was made to use the heavy bombers both of the R.A.F. and U.S.A.A.F. in an attempt to cripple the transport systems, first of France and Belgium and later of Germany, as a preliminary to landings on the Continent.(1) Estimates made by SHAEF of the effort required were considered to be grossly optimistic and independent estimates were offered to the Air Staff and were finally adopted by Air Ministry. This involved an examination of a large number of marshalling yard targets in consultation with railway experts to determine the density of bombs to be aimed at and the best disposition of aiming points. Probability grids based on the latest accuracy parameters were made in order to facilitate the problems of obtaining the expectation of hits on a large number of irregularly shaped targets and the results were used not only to appraise the total tonnage requirements for the plan but also, when the operation started, to calculate the force requirements for each operation separately. The results of the attacks were carefully studied and compared with the forecast which was found to be reasonably accurate.

This was followed by a similar appraisal of a series of airfield targets which were part of the same pre-assault plan and then of ammunition dumps and, finally, the coastal batteries of the cover plan. Indeed from the beginning of 1944 until D-day operational planning work of this nature became a constant feature of the O.R.S.'s activities. Nor was there much respite after the landing for as soon as the troops were held up in Normandy the problem of close support arose with targets such as troops or tank concentrations, the destruction of villages to block vital roads and defence positions of all kinds. It was evident with many of these latter targets that the inflicting of a high degree of physical damage on the small dispersed sub-targets would involve prohibitive effort and great importance was therefore placed on positioning our troops as near to the target as possible so that full advantage could be taken of the 'stunning' effect which was known to last for only a short time. The dangers of being too near are obvious and in order to find the best compromise, bombfall patterns were carefully studied and a 'bomb line' representing the smallest safe distance to the aiming point to which our troops could approach was produced.

Concurrently with the planning for Operation Overlord the question of combatting the V-weapon offensive by knocking out launching sites, interfering with transport and attacking factories and store places was considered. These targets came on to the Bomber Command programme at the end of 1943 and as they later assumed greater importance typical targets were reviewed from the weapon effectiveness and force requirement aspect in order to ensure the most efficient use of the force available. The

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(1) A.H.B. Narr. 'The R.A.F. in the Bombing Offensive against Germany, Vol.VI Chap.I.

matter received more and more attention as the menace grew and, finally, in July 1944 the whole question was referred to the Combined Operations Planning Committee. A member of Bomber Command O.R.S. was co-opted onto the committee and with the collaboration of the Operations Analysis Section of the VIIIth Air Force recommendations as to the type of bombs and fusing together with required densities for the various types of targets were made.(1) The effort required in the case of Bomber Command to give a 50 per cent probability of reducing these targets was calculated.

On 18 October 1944 Bomber Command O.R.S. were called at very short notice to a consultation with representatives of the Directorate of Bomber Operations, Air Ministry, R.E.8 and the Operations Analysis Section of the VIIIth Air Force to provide information on the forces required to destroy the bridges over the Rhine between Basle and Emmerich. This information was required for a conference to be held at SHAEF on the following day at which the feasibility and desirability of this project was to be discussed. At this meeting the weapon requirements and numbers of hits required were calculated on the basis of the data as to the capabilities of the bomber forces provided by the two research sections.

The next of these planning tasks which is worthy of mention was in connection with the bombing of submarines under construction. In this case R.E.8 advised that a direct hit or a near miss within 20 feet of a submarine under construction was required if its building was to be substantially delayed. The method of calculating the force requirement adopted in this case was given the expected standard deviation of the bomb pattern, to calculate the number of bombs which it was necessary to drop in order to achieve a 50 per cent and a 75 per cent chance of a hit on a rectangle of area equal to the plan area of the submarine plus the near miss distance assuming that the centre of the rectangle was at the same distance from the centre of the distribution as the most distant submarine was from the centre of the slips, which would, it was assumed, be the aiming point. The figures thus arrived at therefore gave slight over-estimates of the forces required to damage 50 per cent and 75 per cent of the submarines on the slips. The results of this enquiry ~~will~~ may be found in Bomber Command Memorandum No. 111.(2)

In November 1944 the O.R.S. were asked to estimate the effort which would be required by Bomber Command to prevent Germany obtaining any oil from the oil plants which were at that time allocated as targets to the bomber forces operating from Great Britain. This involved determining the relationship between the density of bombing achieved and the time the

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(1) A.H.B./IIH/241/22/3 (Bomber Cmd. O.R.S. Int.Mem. No.108).

(2) A.H.B./II3/1773A.

plant was out of operation and from that obtaining the optimum density of bombfall. This was done by using the results of past operations obtaining data on the accuracy of American attacks from the Operations Analysis Section of the VIIIth Air Force and on the activity of the plants on various dates from R.E.8. From this it proved possible to estimate the optimum density of bombfall, which was one ton per acre, and also to provide estimates which proved reasonably accurate of the length of time which such densities would put the plants out of action.(1)

In all previous calculations of force requirements the systematic and random errors of bombing were compounded and no account was taken of their relative magnitudes. It was in effect assumed that the bombs would fall in a normal probability pattern about the aiming point with a standard deviation equal to the square root of the sum of the squares of the standard deviation of the mean points of impact of a series of raids about the aiming point and the average standard deviation of the bombs in a raid about their M.P.I., and probabilities of hits and expected densities were computed on this basis. Whilst this provides the average results over a number of raids there will clearly be considerable variation from raid to raid. It was decided at this stage that it was necessary to have a more realistic picture of what actually happened in order to take this variation into account. A short note on an approximate method of specifying the probability that the density of bombing at the aiming point would attain or exceed a given figure was accordingly written and the formulae evolved were used for the calculations in hand on forces required for the attack on oil. This note is Bomber Command O.R.S. Memorandum No. M.113.(2)

Whilst the formulae evolved take the systematic and random errors into account separately they are based on two simplifying assumptions which make them only approximate. The first of these is that the distribution of bombs can be treated as if bomb density were a continuous smooth variable decreasing with distance from the centre of the bomb pattern, in accordance with the normal two-dimensional probability equation. If the target is large enough for the expected number of hits on it to be considerable, taking into account the number of bombs to be dropped, and yet small enough in relation to the standard deviation of the pattern for the change of density over it to be small, the approximation will be close. However, if the target and the number of bombs to be dropped is such that the expected number of hits is small the discontinuity of the bombfall distribution must be taken into account. The other simplifying assumption is that the standard deviation of the bombs about their centroid is the same from raid to raid. In practice, however, this

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(1) A.H.B./IID3/1713A.
(2) A.H.B./IIH/241/22/3.

varies from raid to raid and the overall effect of such variation is to decrease the probability of achieving a given result with a given quantity of weapons.

This method was elaborated a little further and put forward in some detail with graphs to assist in rapid determination of the required answers in Bomber Command O.R.S. Report No. 124. A further report with more practical detail and containing current figures of Bomber Command accuracy was produced at the instance of the Air Staff as Bomber Command O.R.S. Report No. S.227.(1) The first note was shown to Dr. Bronowski, one of the mathematicians of R.E.8 with whom the writer of the note was in contact at the time on weapon effectiveness matters and, as a result, he worked on the problem of producing more exact formulae and determining the errors caused by the various approximations made. A joint paper resulting from this work was drafted later.

Further work of this type on problems of close support bombing, attacks on the German railway system, and on an underground factory will be found in Bomber Command O.R.S. Report Nos. B.229,(2) B.231(3) and B.234.(4) There were in addition other similar problems tackled which did not give rise to formal reports.

Area Attacks

During 1943 and early 1944 Bomber Command O.R.S. was keeping in touch with the work on weapon effectiveness which was being done, mainly by R.E.8, and advising the Air Staff of the Command on the relative merits of different types of bomb for area attack. At this stage the accuracy attainable was such that the full force of the Command was necessary for each attack and force requirements calculations were therefore not needed. In the winter of 1944/45 when a return to area bombing took place it was clear that the increase in accuracy of the Command was such that serious over-hitting was occurring. The O.R.S. was therefore asked to look into the question of the size of forces required for towns of different areas and also into the question of the desirable distance apart of aiming points when the target was large.

The mathematical problems raised by area bombing are far from simple. The complications are due to the fact that the density of bombing cannot be treated as constant over the whole target area and the amount of damage done is a negative exponential function e^{-kn} of the density of bombing. The whole subject is discussed exhaustively in A.W.A.S. Departmental Note No. 11. Bomber Command O.R.S. using equation 13 of that paper, carried out calculations on the tonnages of bombs to be dispatched to destroy 70 per cent of the buildings in a circular target of varying radius and using techniques of different accuracy. This

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(1) A.H.B./II/39/1/1. (2) (3) AHB2. uninduxed
(4) Air Min. File C.M.S. 82/II.

information was expressed as curves on which the radius of the target at which it was desirable to use two or more aiming points was indicated. This note, which was passed to Intelligence for their use, is included in the series of Internal Memoranda as Bomber Command O.R.S. No. M.112.(1)

At a later date the Commander-in-Chief requested the O.R.S. to make an appreciation of the effort required to destroy all the remaining built-up areas in Germany of a size of over 100 acres. The irregularity of these made the use of the curves referred to in the previous paragraph rather difficult and instead of this, circles were drawn on Kodatrace showing density contours for raids of different sizes with the accuracies appropriate to different marking techniques. With the aid of these the number of aiming points on each built-up area and the required size of the attacks were determined and, from this, the necessary tables were drawn up. The note prepared, which was to be used in an appraisal by the Air Staff of the economic effects of carrying out such a campaign was issued in the Internal Memorandum Series as Bomber Command O.R.S. No. M 114.(2)

Following on this a further mathematical attack on the problems of the optimum size of a raid was made in which the proportions of the tonnage dropped was divided into that necessary for the required amount of destruction, the additional quantity hitting the destroyed area and thus wasted in overhitting, and that which fell outside the area of the target that was destroyed. Curves indicating the proportions in each of these categories as the tonnage dropped increased were produced for various combinations of random and systematic error. This work, completed too late to be used before the conclusion of hostilities is published as Bomber Command O.R.S. Report No. ? .(3)

Besides these larger questions small problems often arose in the field of bomb performance and force requirements which are too numerous to detail but it is probably of interest to note two which though never actually leading to operational use illustrate the diversity of such questions. The first related to Chemical Warfare and, starting from a paper by the Army School of Chemical Warfare at Porton on lethal densities, full details of bombloads and force requirements for a full-scale gas retaliation on German cities was prepared and incorporated in Operation Orders. The other which cropped up in September 1944 and of which no record is kept concerned the dropping of food from high altitude into Warsaw.

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(1) A.H.B./IIH/241/22/3.

(2) Ibid.

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